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Understanding drivers of intention to reduce heating-related energy use in five European countries

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Abstract Since heating-related energy consumption is one of the main sources of greenhouse gas emissions and accounts for a large part of domestic energy use in Europe, reducing heating-related energy consumption has great potential to reduce Europe's greenhouse gas emissions. This study examines which factors determine people's intention to decrease heating-related energy usage, specifically lowering the temperature in winter. It was part of a larger European project focused on promoting energy reduction. This study presents a smaller-scale

model tested among 363 individuals from five pilot countries, i.e., Belgium ($n = 58$), Croatia ($n = 82$), Germany ($n = 105$), Greece ($n = 33$), and Portugal ($n = 85$). We applied three robust theoretical frameworks: the Theory of Planned Behaviour, the Value Belief Norm Theory, and the Prototype Willingness Model. We conducted a confirmatory factor analysis to ensure construct validity, followed by a structural equation model. Our findings suggest that willingness (from the Prototype Willingness Model) is the most important predictor in explaining someone's intention

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to reduce heating-related energy consumption. Additionally, perceived behavioural control, subjective norms, and attitudes (part of Theory of Planned Behaviour) also play an important role in predicting the intention to reduce energy consumption. Lastly, personal moral norms (from the Value Belief Norm Theory) have a significant impact, but their effect is moderate compared to the other predictors.

Keywords Energy efficiency · Behaviour change · Behavioural modelling · Heating consumption · Household energy behaviour

Introduction and theoretical background

In Europe, heating is the number one source of residential energy consumption, with an average of 63% of total energy consumption for households in Europe (Eurostat, 2021). This share can fluctuate highly across countries: while some countries, such as Malta with 18%, have a lower share, other countries use more energy for residential heating. Luxembourg for example, uses up to 82% of its total household energy consumption for heating (Eurostat, 2021). Generally though, the heating of homes is one of the main sources of greenhouse gas emissions (GHGE), responsible for 20% of GHGE in the US, and 25% of GHGE in the EU (Goldstein et al., 2020; Jakučionytė-Skodienė et al., 2022). Residential and commercial buildings collectively contribute over 30% of GHGE (Costa et al., 2013), highlighting the urgent need for interventions in this domain.

While conventional strategies like energy efficiency renovations and the installation of renewable energy systems are pivotal in curbing energy consumption (Feliús et al., 2020), studies have also emphasized the role of occupant behaviour in achieving meaningful reductions (Lopes et al., 2012; Steemers & Yun, 2009). This could be curtailment behaviour such as lowering the thermostat set point or reducing the number of hours that indoor heating is switched on. Earlier research has underlined the potential savings of energy behaviour in service buildings, as well as indicating the lack of understanding of determinants influencing heating-related energy behaviour changes (Lopes et al., 2012). As a consequence, there is a growing interest in comprehensively understanding the behavioural determinants

for individuals' intention to reduce their overall energy consumption, particularly focusing on heating-related energy consumption.

When looking at theoretical behaviour models to explain behaviour change, the Theory of Planned Behaviour (TPB) of Ajzen stands out as a robust framework for understanding behavioural intention (Ajzen, 1991). It has been widely applied across various sustainable domains including driving behaviour, (Elliott et al., 2003), healthy eating (Conner et al., 2002) and green purchasing behaviour (Carfora et al., 2019; Liobikienė et al., 2016). However, the model has also been criticised, particularly because it mainly focuses on the rational decision-making process (Gao et al., 2017) and disregards unconscious and contextual influences (Manstead, 2009; Miller, 2017). To counter this criticism, TPB is often extended in sustainability research by incorporating additional variables or integrating it with alternative behavioural frameworks, aiming to improve explanatory power (Perugini & Bagozzi, 2001; Rivas et al., 2006).

That is why, in line with suggestions of researchers on how to implement TPB in a more nuanced and exhaustive way (Conner, 2015; Rhodes, 2015), we have developed a comprehensive behavioural model that combines three behavioural models. This combination aims at accounting for the influence of a rational, a socially reactive and a moral path to decision-making, providing a more nuanced understanding of how heating-related energy behaviour change occurs. First, as outlined above, TPB aims to predominantly explain the rational path to decision-making, i.e. the more controlled elements in the human decision-making process (Ajzen, 2011). However, people also make behavioural decisions in a more unconscious way, changing behaviour in function of other people's behaviour, such as household members, without deliberately making the decision. To account for this more socially-reactive behavioural change, we add the Prototype Willingness Model (PWM). This theoretical model takes into account how open people are to certain images of other people and how willing they are in turn to perform a certain behaviour (Gerard et al., 2008). While TPB relies on a reasoned action process, PWM considers behaviour as a more spontaneous and reactive process (Ajzen, 2011). Lastly, energy consumption reduction is a type of environmental behaviour, which could be motivated by a personal obligation or moral norm to perform

this type of behaviour. Someone's intention could be influenced by their moral obligation to reduce their impact on the climate. Therefore, we combine TPB and PWM with the Value-Belief-Norm Theory (VBN theory), which predominantly focuses on the moral decision-making path (Steg et al., 2005; Stern et al., 1999). In TPB and PWM, moral consideration is not explicitly present, but it is key to understanding conservation behaviour (Kaiser et al., 2005). VBN theory accounts for the moral pathway to behavioural decision-making through a person's personal sense of responsibility and moral norms and how those influence behavioural decision-making.

This study is part of the broader NUDGE project (Cordis, 2020), which aims to understand the motivations behind reducing energy consumption. Within this project, we have developed an initial baseline survey between February and July 2021, in which we collected data from 3098 individuals across 29 European countries, applying the integrated theoretical framework mentioned above. Our findings from that baseline survey confirmed the proposed combined theoretical model (Conradie et al., 2023), and were the basis of energy consumption profiles based on disparities in energy-saving behaviours (Karaliopoulos et al., 2022). This study specifically focuses on the second phase of the project, where longitudinal pilot projects were set up in five countries: Belgium, Germany, Portugal, Croatia and Greece. The pilot projects aimed to examine household energy and gas reduction, air quality improvements and self-consumption of renewable energy. At the start of the pilot projects, a survey was distributed among 363 pilot participants to assess their intention to lower the temperature in winter.

By applying a theoretical model combining TPB, PWM and VBN theory, the goal of this paper is to obtain a more comprehensive understanding of heating-related energy behaviour intention changes. On the one hand, we want to compare the application of the combined behavioural model in the pilot studies with the results from the baseline survey of the overarching research project, to assess the potential of this combined behavioural model. In doing so, we want to examine whether this integrated theoretical model can offer a more comprehensive understanding of energy-saving behaviour intentions compared to past studies that have applied an isolated behavioural model (e.g. focusing solely on TPB). On the other hand, we aim

to evaluate potential disparities in intention to lower the temperature in winter among the participants in our five pilot studies. Below, we will therefore delve deeper into the use and implications of these integrated theories.

Theory of Planned Behaviour (TPB)

Ajzen's Theory of Planned Behaviour (TPB) is a behaviour model that focuses on the rational decision-making process (1991). It has been widely applied across various domains and is a robust theory of human behaviour (Judge et al., 2019). When looking at sustainable research, it has been applied to topics such as sustainable housing purchases (Judge et al., 2019), recycling behaviours (Tonglet et al., 2004) and sustainable mobility (Asadi et al., 2021; Shalender & Sharma, 2021). Looking at energy behaviour specifically, TPB has proven a robust framework for renewable energy adoption (Hesselink & Chappin, 2019; Irfan et al., 2021; Michelsen & Madlener, 2013) and energy-saving behaviour (Conradie et al., 2023; X. Liu et al., 2020; Nie et al., 2019; Tan et al., 2017).

TPB states that three key variables play a role in predicting an individual's intention to engage in or adopt a particular behaviour: attitude, perceived behavioural control (PBC), and subjective norms (SNs). Attitude encompasses an individual's evaluation of a specific behaviour, with people who have a positive attitude towards a certain behaviour being more inclined to adopt it or participate in it. PBC refers to a person's perceived capability to engage in a certain type of behaviour, which has a positive effect on one's intention to adopt that type of behaviour. Lastly, SNs are characterized by a person's perceptions of the social expectations of people close to them regarding a specific type of behaviour. If you score high on subjective norms related to a certain type of behaviour, you would have a higher intention to adopt that type of behaviour (Ajzen, 1991). When looking at past research, multiple studies found attitude, PBC and SNs to be significantly associated with someone's intention to save (heating-related) energy (Conradie et al., 2023; Nie et al., 2019).

Building upon this foundation, we formulate the following hypotheses:

H1: Attitude towards energy reduction is positively associated with the intention to reduce energy

consumption behaviour by lowering the temperature in winter.

H2: PBC is positively associated with the intention to reduce energy consumption behaviour by lowering the temperature in winter

H3: SNs are positively associated with the intention to reduce energy consumption behaviour by lowering the temperature in winter.

Prototype Willingness Model (PWM)

The Prototype Willingness Model (PWM) extends TPB by focusing on socially reactive behaviour, meaning behaviour that typically arises as an unplanned response to social situations, rather than being the result of deliberate thought or planning (Gerrard et al., 2008). It was originally developed to explore the socially reactive pathways to decision-making in the domains of healthcare and risk behaviour, for example smoking or drinking. While it was initially applied mostly to adolescents, it has also since been used to assess behaviour of adults (Gerrard et al., 2008). Additionally, despite its initial emphasis on understanding risk and health-related behaviours, a limited number of researchers have also successfully extended its application to the domain of sustainability (Frater et al., 2017; J. Liu et al., 2023; Ratliff et al., 2017).

Essentially, PWM proposes that an individual's willingness to engage in a particular activity is determined by the favourability and similarity of prototypes associated with that activity. Prototype favourability encompasses how individuals perceive those engaging in a certain activity, while prototype similarity relates to the degree of resemblance individuals perceive between themselves and the prototypes. The combined impact of prototype favourability and similarity impacts an individual's willingness to undertake that specific behaviour. In the context of health-risk behaviour, that implies that the more positive someone's evaluation of a prototypical person is, and the higher the perceived similarity to that prototype, the greater their willingness to engage in a certain type of health-risk behaviour (Rivis et al., 2006).

The combination of PWM with TPB is especially interesting because TPB does not really account for social influences (Rivis et al., 2006). In the context of health-risk behaviour, a number of studies have extended TPB with PWM successfully (Rivis

et al., 2006, 2011; Zhao et al., 2023; Zimmermann & Sieverding, 2010), finding greater explained variability with the extended behavioural model compared to using TPB alone. Research using TPB and PWM in a sustainability context is limited, but Ratliff et al. found that a positive attitude towards environmentalist prototypes predicted sustainable donation behaviour (2017), and Frater et al. identified the importance of social pressure for teenagers' cycling behaviour (2017).

Building upon this theoretical framework, we propose the following hypotheses:

H4: Prototype favourability is positively associated with the willingness to reduce energy consumption behaviour by lowering the temperature in winter.

H5: Prototype similarity is positively associated with the willingness to reduce energy consumption behaviour by lowering the temperature in winter.

H6: Willingness to reduce energy consumption behaviour is positively associated with the intention to reduce energy consumption behaviour by lowering the temperature in winter.

Value-Belief-Norm Theory (VBN)

In addition to TPB and PWM, we also integrate the Value-Belief-Norm (VBN) theory in our behavioural model, which places emphasis on moral and personal norms pertaining to sustainable behaviour. Stern et al. (1999) revealed that individuals are more inclined to participate in sustainable practices when they perceive a moral obligation to do so. This means that personal moral norms, which encompass one's beliefs regarding what is ethically right or wrong, play a significant role in predicting sustainable behaviour (Kaiser et al., 2005).

Because of its prominence within the research field of sustainability, there is robust evidence showcasing the value and predictive power of VBN theory in topics such as predicting reductions in energy consumption (B. Wang et al., 2018), influencing intentions toward renewable energy adoption (Fornara et al., 2016) and behaviours related to climate mitigation (Zhang et al., 2020). Earlier research has proven the compatibility between TPB and VBN theory to increase explained variance for pro-environmental behaviour in the context of intention to choose green lodging and willingness to pay for park conservation (Han, 2015; López-Mosquera & Sánchez, 2012).

Moreover, it has also been applied in research on environmental behaviour in a private-sphere context, where was predictive of intention to adopt pro-environmental personal practices (Gkargkavouzi et al., 2019)

VBN theory highlights the causal pathway between awareness of consequences and ascription of responsibility (Steg et al., 2005). This causal relation implies that individuals must first be aware of the consequences of their actions before they can feel a sense of responsibility for energy-related issues. Subsequently, the awareness of consequences, and in turn the ascription of responsibility, are predictive of personal moral norms, which, in turn, predict intentions.

Based on these findings, we propose the following hypotheses:

H7: Awareness of consequences is positively associated with ascription of responsibility.

H8: Ascription of responsibility is positively associated with personal moral norms.

H9: Personal moral norms are positively associated with the intention to reduce energy consumption behaviour by lowering the temperature in winter.

A full overview of the integrated behavioural model combining TPB, PWM and VBN theory can be found in Fig. 1.

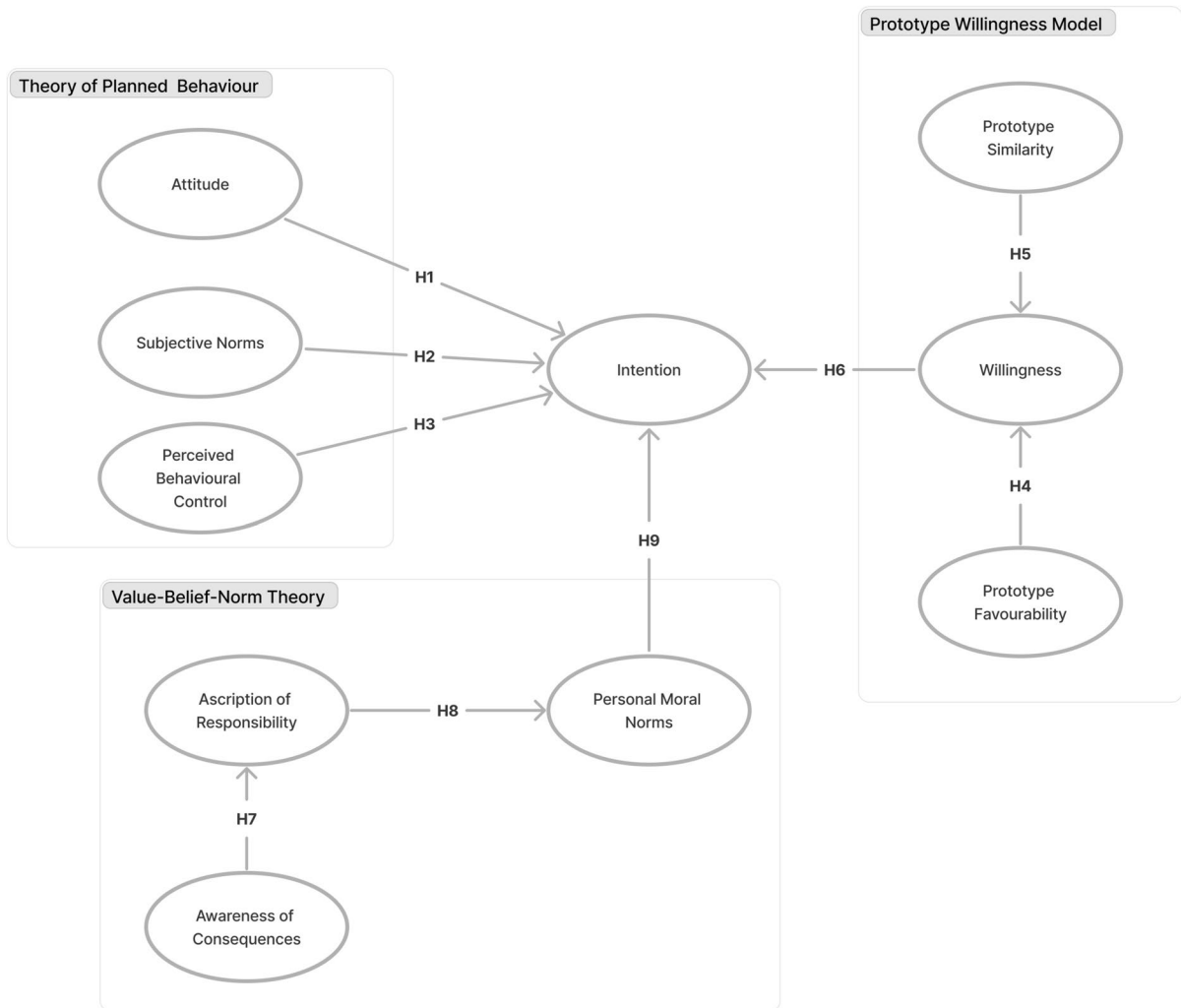


Fig. 1 Theoretical model, combining Theory of Planned Behaviour, Prototype Willingness Model and Value-Belief-Norm Theory

Method

Research context, procedure and sample

As mentioned before, this study is part of the broader NUDGE project (Cordis, 2020), which aims to understand the motivations behind reducing energy consumption. In a first baseline survey, data was collected from 3098 individuals across 29 European countries. The results are reported in Conradie et al. (2023).

By contrast, our current study aims to evaluate the potential of the combined behavioural model in the context of five pilot projects, and to explore differences in behaviour among participants in the pilot projects. The pilot projects took place in five countries, i.e., Belgium, Germany, Portugal, Croatia and Greece. Because each pilot had a slightly different focus, we tailored each pilot survey to match each pilot's unique goals. For instance, the Belgian pilot examined how intergenerational learning affects household energy use, while the Portuguese pilot focused on improving air quality and reducing energy consumption. Meanwhile, Germany and Croatia concentrated on boosting self-consumption of renewable energy, and the Greek pilot aimed to cut gas usage. Despite these diverse objectives, all pilot surveys included an identical section on reducing winter heating consumption, which are comparable across surveys. The results for this article were derived from these sections. Surveys were conducted before any interventions in the pilot projects began.

Our survey used a convenience sample drawn from pilot participants. Inclusion criteria varied: Belgian participants were recruited through a school for gifted children, Greek participants were users of energy management software, and German participants were users of a smart charging system with photovoltaic installations. Croatian participants were members of a local energy cooperative, and Portuguese participants were families with children under 12 who lived near Porto, had Wi-Fi at home, and didn't plan to move

within a year. All participants were over 18, aware of the study's aims, and provided informed consent.

Because this survey was distributed among the participants of the pilot study, we had a considerably smaller sample than our initial baseline study. In total, we maintained 363 participants throughout our pilots who completed the questions in our behavioural model. The largest group of participants was German ($n = 105$), and the smallest group was Greek ($n = 33$). Our sample comprised a higher percentage of men than women (73.83%). The average year of birth was 1975 (corresponding to 47 years old). An overview of the age, gender, and number of participants per pilot can be found in Table 1.

Measures

We developed a questionnaire including socio-demographic information and the latent constructs of TPB, PWM and VBN theory. To develop the scales for our behavioural models, we adapted questions from the relevant models to suit our study's purposes. For TPB, we adapted formulations as suggested by Ajzen in the context of energy reduction (1991; La Barbera & Ajzen, 2021). For PWM, we referenced Gerrard et al. (2008), combined with insights from various fields (Van Gool et al., 2015). Lastly, for VBN theory, we repurposed items from Abrahamse & Steg (2009) and adapted them to the specific context of this research.

The survey was initially created in English and later translated into the languages spoken in the different pilot regions: German, Croatian, Dutch, Portuguese, and Greek. Native speakers within the consortium aided in the translation process. We used a backtranslation method (Brislin, 1970) where the items were first translated into the native languages and then translated back into English. If any disparities with the original English items were identified, the process was repeated until a satisfactory translation was achieved. A list of items for all observed variables can be found in Table 2.

Table 1 Age and gender across the 5 pilots

	Belgium ($n = 58$)	Croatia ($n = 82$)	Germany ($n = 105$)	Greece ($n = 33$)	Portugal ($n = 85$)
Number of men (%)	31 (53%)	76 (93%)	92 (88%)	32 (80%)	44 (51%)
Mean age (SD)	43.67 (4.75)	48.44 (12.34)	57.34 (10.45)	35.05 (8.10)	40.46 (7.66)

Table 2 Latent constructs with item id, Cronbach's α , Spearman Brown ρ , factor loadings, and item text for all observed variables

Latent variable	Item id	α	ρ	Factor Loadings	Item text	
Intention	INT_SPEC_1	0.86	0.95		I intend to save energy by lowering the temperature setting in winter.	
	INT_SPEC_2				0.79	There is a chance that I save energy by lowering the temperature setting in winter.
Attitude	ATT_1	0.83	0.74		Disadvantageous - advantageous	
	ATT_2				0.96	Foolish – wise
Perceived Behavioural Control (PBC)	PBC_1	0.70	0.68		I have the capabilities to save energy by lowering the temperature setting in winter.	
	PBC_2				0.79	If it were entirely up to me, I am confident that I could save energy by lowering the temperature setting in winter.
Subjective Norms (SN)	SN_1	0.79	0.80		Most people who are important in my life would approve that I save energy by lowering the temperature setting in winter.	
	SN_2				0.82	Most people who are important in my life save energy by lowering the temperature setting in winter.
Personal Moral Norms	PERS_NORM_1	0.76	0.74		I feel morally obliged to reduce my energy use, regardless of what other people do.	
	PERS_NORM_2				0.75	I feel guilty when I use a lot of energy.
	PERS_NORM_3				0.66	I feel good about myself when I do not use a lot of energy.
Ascription of Responsibility	ASCR_RESP_1	0.87	0.85		I take joint responsibility for the depletion of energy resources.	
	ASCR_RESP_2				0.92	I feel jointly responsible for the greenhouse effect.
Awareness of Consequences	C_AWARE_1	0.74	0.60		Energy conservation contributes to a reduction of global warming.	
	C_AWARE_2				0.90	The increasing energy demand is a serious problem for our society.
	C_AWARE_3				0.66	The increasing shortage of energy sources is a serious problem for our society
Prototype Favourability	PROT_FAV_1	0.83	0.76		Conscious	
	PROT_FAV_2				0.90	Smart
	PROT_FAV_3				0.68	Green
Prototype Similarity	PROT_SIM_1	0.91	0.91		Do you resemble the typical person who saves energy by lowering the temperature setting in winter?	
	PROT_SIM_2				0.92	I am comparable to the typical person who saves energy by lowering the temperature setting in winter.
Willingness	WILL_1	0.62	0.63		You lower the temperature setting in all unused rooms when you are at home all day.	
	WILL_2				0.70	You lower the temperature setting when you leave home.
	WILL_3				0.45	You keep the doors closed to prevent heat loss.

Because this research was part of a broader survey, some constructs were measured using two items in order to reduce survey fatigue. To assess reliability of all items, we followed recommendations by Eisinga et al. (2013), relying on Spearman-Brown (ρ) for two-item constructs and Cronbach's α for the three-item constructs. All two-item constructs had satisfactory Spearman-Brown values above 0.70. All Cronbach's α and factor loadings were above the conventional threshold of 0.70, except for willingness, which fell slightly below the threshold with a Cronbach's α of 0.62.

All statements could be answered using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree), unless mentioned otherwise. For socio-demographic information, participants were asked to give their age (birth year) and gender ('female', 'male' or 'other').

Intention

Two items measured the respondent's intention to reduce heating consumption by lowering the temperature in winter, with an example item being "I intend to save energy by lowering the temperature in winter" ($\rho = 0.86$).

Attitude

Attitude towards lowering the temperature in winter was measured using a two-item semantic differential 7-point scale. The statement provided was "for me, saving energy by lowering the temperature setting in winter is...". Participants were asked to indicate their agreement on two items, item 1 being '1 = disadvantageous, 7 = advantageous' and item 2 being '1 = foolish, 7 = wise'. ($\rho = 0.83$)

Perceived Behavioural Control

A respondent's perception of his own capability to lower heating-related energy consumption was measured using two items. An example item is "I have the capabilities to save energy by lowering the temperature setting in winter" ($\rho = 0.70$).

Subjective Norms

We used two items to measure a participant's own estimation of the social pressure to lower heating-related energy consumption. An example item is "most people who are important in my life save energy by lowering the temperature setting in winter" ($\rho = 0.79$).

Personal Moral Norms

To measure personal moral norms related to reducing one's heating-related energy consumption, we used three items, with an example item being "I feel morally obliged to reduce my energy use, regardless of what other people do" ($\alpha = 0.76$).

Ascription of Responsibility

To measure the sense of responsibility a participant has for energy-related issues, we used two items. An example item is "I take joint responsibility for the depletion of energy resources" ($\rho = 0.87$).

Awareness of Consequences

A respondent's awareness of the consequences of energy-related actions was measured using three items. An example item is "energy conservation contributes to a reduction of global warming" ($\alpha = 0.74$).

Prototype Favourability

To measure prototype favourability, we asked participants what they think about someone who saves energy by lowering the temperature setting in winter. We asked them to indicate to what extent this type of person has the following properties on a 5-point Likert scale (1 = 'not at all', 5 = 'totally') for three items, with item 1 being "conscious", item 2 being "smart" and item 3 being "green" ($\alpha = 0.83$).

Prototype Similarity

We measured how much a participant resembled a person that saves energy by lowering the temperature setting in winter using two items. An example item is "I am comparable to the typical person who saves

energy by lowering the temperature setting in winter” ($\rho = 0.91$).

Willingness

A participant’s willingness to lower heating consumption was measured using three items which could be answered with a 5-point Likert scale (1 = ‘extremely unlikely’, 5 = ‘extremely likely’), with an example item being “you lower the temperature setting in all unused rooms when you are at home during the day” ($\alpha = 0.62$).

Analytic approach

Bivariate correlations were calculated to evaluate the level of association both within and between constructs, as demonstrated in Table 3. To test the hypotheses, we applied structural equation modelling to the collected data using Jeffrey’s Amazing Statistics Program (JASP) (Love et al., 2019). Prior to establishing our measurement model and our structural equation model (Anderson & Gerbing, 1988), we first performed a preliminary analysis of the control variables, in order to determine which variables to include as categorical predictors regressed on intention in the structural equation model. We tested differences between gender using a Welch two-sample t-test, and differences between age using Pearson correlation. Additionally, we assessed differences between the pilot studies using one-way ANOVA. If any significant differences were found, we included the variable as a categorical predictor in our first

structural equation model to assess whether there is an impact on the results.

Second, we established our measurement model with the purpose of determining whether the observed variables (i.e., the questions or items posed to participants) reliably reflected the proposed latent variables (i.e., the constructs we were trying to measure). Subsequently, we determined the fit of our model using three indices as recommended by Schreiber et al. (2006). We used the Tucker Lewis index (TLI) and the Comparative Fit Index (CFI), both ranging from 0 to 1.00, with values above 0.9 indicating good fit. Additionally, we considered the root mean square error of approximation (RMSEA), with values below 0.05 indicating good fit and values between 0.06 and 0.08 suggesting adequate fit (Ponnet, 2014). We allowed error co-variance for similarly phrased items. The threshold for statistical significance was set at $p = 0.05$.

Results

Preliminary analysis

The average intention to reduce heating-related energy consumption by lowering the temperature in winter was 3.621 ($SD = 1.00$). In terms of control variables, a Welch two-sample T-test did not reveal any statistical differences across gender for the intention to reduce heating consumption ($t = 1.946$, $p = 0.053$). Similarly, we did not find any statistical differences between age and intention (Pearson correlation, $\rho = -0.026$, $p < 0.628$). A One-way

Table 3 Pearson correlation table of all latent constructs ($p < 0.05 = *$, $p < 0.01 = **$)

	1	2	3	4	5	6	7	8	9
Intention (1)									
Attitude (2)	0.49**								
Perceived Behavioural Control (3)	0.51**	0.30**							
Subjective norms (4)	0.50**	0.30**	0.36**						
Personal Moral Norms (5)	0.46**	0.29**	0.30**	0.39**					
Ascription of Responsibility (6)	0.32**	0.24**	0.24**	0.28**	0.51**				
Awareness of Consequences (7)	0.28**	0.25**	0.19**	0.09	0.33**	0.33**			
Prototype Favourability (8)	0.46**	0.40**	0.40**	0.28**	0.45**	0.37**	0.28**		
Prototype Similarity (9)	0.58**	0.42**	0.42**	0.43**	0.45**	0.30**	0.19**	0.44**	
Willingness (10)	0.51**	0.37**	0.35**	0.31**	0.37**	0.26**	0.20**	0.38**	0.44**

ANOVA ($F(4, 358) = 2.601, p = 0.036$) did reveal a difference in intention across the five pilot studies. A post-hoc Tukey test revealed that Portugal and Germany differed significantly from one another ($p = 0.043$), with the participants from Portugal ($M = 3.80, SD = 0.92$) having a significantly higher intention to lower the temperature in winter than the participants from Germany ($M = 3.40, SD = 0.86$). Because of this statistically significant difference, we included the pilot locations as a categorical predictor regressed on intention in our structural equation model.

Subsequently, we performed Pearson correlation analyses on all our latent constructs (i.e., the latent constructs included in TPB, PWM and VBN theory). As shown in Table 3, all constructs were significantly related to each other. We found significant correlations for intention and attitude ($r = 0.49, p < 0.001$), as well as between intention and PBC ($r = 0.51, p < 0.001$), and intention and SNs ($r = 0.50, p < 0.001$). We also found a significant correlation between intention and personal moral norms ($r = 0.46, p < 0.001$) and willingness ($r = 0.51, p < 0.001$). The lowest correlation was between consequence awareness and SNs ($r = 0.09, p = 0.08$).

Confirmatory factor analysis

To assess the fit of our model, we first performed a confirmatory factor analysis. As shown in Table 2, we did not have any items with factor loadings below 0.4. Our initial fit was adequate, with TLI = 0.913, CFI = 0.935 and RMSEA = 0.060. Following our modification indices and when possible due to similar item phrasing, we allowed error covariance between two pairs of items: CONSEQ_AWARE_2 and CONSEQ_AWARE_3, and PROT_FAV_1 and PROT_FAV_4. This increased our model fit (TLI = 0.930, CFI = 0.948 and RMSEA = 0.054). Additionally, reliability of our constructs was generally acceptable with all Cronbach's α or Spearman-Brown (ρ) values above the 0.7 threshold, except for willingness ($\alpha = 0.62$). Deleting an item for willingness did not result in an increase of Cronbach's α so we proceeded with the construct as is. Finally, all model fit indices meet minimum fit requirements, and as a result, we could proceed with our structural equation model.

Structural equation modelling

Preliminary analysis revealed that there was a statistically significant difference in the intention to lower temperature in winter between the German and Portuguese pilot. Therefore, we performed a first analysis using pilot locations as categorical predictors regressed on intention. We did this to assess whether location had an impact on our results. Portugal was used as a reference category. Our results showed a poor fit, with TLI = 0.823, CFI = 0.849 and RMSEA = 0.076. Moreover, we did not find any statistically significant results for pilot location on intention in our model. Thus, we proceed without pilot location as a categorical predictor. The fit of our overall model was satisfactory, with TLI = 0.900, CFI = 0.918 and RMSEA = 0.064.

Our findings revealed statistically significant outcomes for all hypotheses. Firstly, considering TPB, we found that attitude ($\beta = 0.178, p < 0.001$), PBC ($\beta = 0.232, p < 0.001$) and SNs ($\beta = 0.274, p < 0.001$) were all significantly associated with intention, confirming H1, H2 and H3, with SNs being the most predictive variable, indicating that turning down the heat in winter is partially reasoned behaviour based on someone's perception of other people's opinions and actions. Moreover, we found confirmation for H6 with willingness, as part of PWM, being significantly associated with intention ($\beta = 0.403, p < 0.001$). Lastly, personal moral norms as part of VBN theory were also predictive of intention, confirming H9 ($\beta = 0.101, p < 0.001$). When looking at predictors within PWM, we found that both prototype favourability ($\beta = 0.271, p < 0.001$) and prototype similarity ($\beta = 0.468, p < 0.001$) were predictive of willingness, confirming H4 and H5. This significant association indicates that the willingness to lower the temperature in winter is in part socially-reactive, based on how someone perceives and relates to the prototype of an energy-conscious person. Lastly, when looking at VBN theory, we found confirmation of both H7 and H8, with awareness of consequences being positively associated with ascription of responsibility ($\beta = 0.567, p < 0.001$), which in turn is predictive of personal moral norms ($\beta = 0.650, p < 0.001$).

We found an explained variance of 69% for intention ($R^2 = 0.693$), 42% for personal moral norms ($R^2 = 0.423$) and 43% for willingness ($R^2 = 0.428$). Moreover, we found an explained variance of 32%

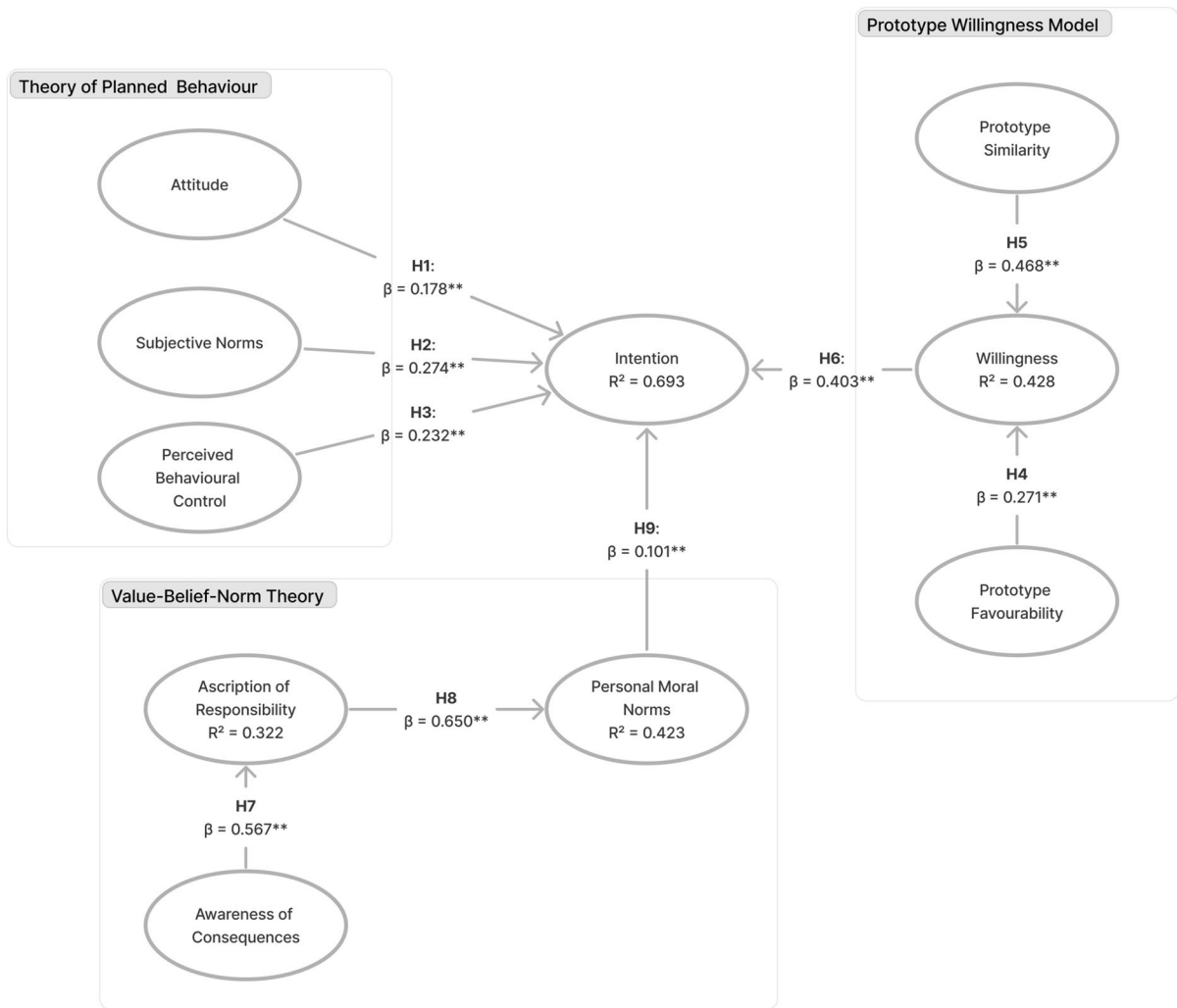


Fig. 2 Results from structural equation modelling ($p < 0.05 = *$, $p < 0.01 = **$), $TLI = 0.900$, $CFI = 0.918$ and $RMSEA = 0.064$

for ascription of responsibility ($R^2 = 0.322$). Figure 2 provides an overview of all results from our structural equation modelling.

Discussion and limitations

Discussion

Since heating is one of the main sources of GHGE and the number one contributor to residential energy consumption in Europe (Goldstein et al., 2020), reductions in space heating energy consumption have significant potential to reduce emissions. Studies

have shown the role of occupant behaviour in achieving energy reductions and the lack of understanding regarding energy-related behaviour changes (Lopes et al., 2012; Steemers & Yun, 2009), implying there is a need to comprehensively understand what determines individuals’ intention to reduce their heating-related energy consumption. By applying a theoretical model combining the rational (TPB), the socially reactive (PWM), and the moral (VBN theory) path to decision-making, this study aims to provide a more exhaustive view of how energy behaviour change occurs. Additionally, we aim to evaluate potential disparities in behavioural intention to lower the temperature in winter among the participants in our pilot

studies in Belgium, Greece, Croatia, Germany and Portugal.

Our model was able to explain 69% of variance for intention, with our results indicating that willingness is the strongest predictor of people's intention to lower the temperature in winter, followed by SNs, PBC and attitude. Personal moral norms is the weakest predictor, although still significant. Thus, while the rational, moral and socially reactive path all contribute to intention to reduce energy-consumption, the socially reactive path has the strongest impact. Additionally, we were able to explain 42% of variance for personal moral norms and 43% of variance for willingness, with prototype similarity being the strongest predictor of people's willingness.

Regarding TPB, we found support for H1, H2 and H3. Both PBC and SNs were more strongly associated with intention, while attitude was a weaker predictor. These results are in line with earlier research (Cheung et al., 2017; Nie et al., 2019), although Liu et al. (2020) found SNs to not have an effect on intention toward household energy conservation.

Regarding PWM, we find support for H4, H5 and H6. Both prototype favourability and prototype similarity had a strong significant association with willingness, which in turn also showed the strongest association with intention, in line with earlier research (Ratloff et al., 2017). Thus, people who think positively of someone that saves energy by lowering the temperature in winter, and those who think they resemble that type of person, are more willing to lower the temperature in winter, which in turn strongly predicts their intention to actually do so. The strong significant association between prototype willingness and prototype favourability and willingness, and in turn with intention, indicates that turning down the heat in winter is partially a socially-reactive behaviour, which people are prone to perform when given the opportunity without prior intention, and partially a reasoned action, as predicted by SNs within TPB being significantly associated with intention.

Regarding VBN theory, we find a less convincing picture. While we find support for H7, H8 and H9, the strength of the association between personal moral norms and intention is modest in comparison to the other associations. Even when a person feels morally obliged to reduce heating-related energy consumption, this is not as predictive for their intention

to lower the temperature in winter compared to the influence of similar people's behaviour.

So, what can be done to stimulate individuals' intention to reduce their heating consumption? Firstly, our research suggests that the socially-reactive path plays a principal role in predicting people's willingness and intention to adapt their energy behaviour, as people seem to be influenced by their evaluation of similar people's behaviour. The significant effects within PWM and from willingness on intention, as well as the significant effect of SNs on intention, emphasize the role of social dynamics in changing energy consumption behaviour. Indeed, earlier research by Ek and Söderholm found that social interactions were an important determinant for electricity-saving behaviours in Swedish homes (2010). Thus, when people can identify and interact with others in their environment whose saving behaviour they evaluate as positive, their own intention to adopt that behaviour could increase. To stimulate energy consumption behaviour, policy makers could focus on identifying which individuals people identify with in a favourable way, and include those individuals in interventions aimed at influencing people's heating consumption. The fact that other people's opinion apparently plays a role in energy-related curtailment behaviour, implies that integrating social norms into policy frameworks could prove a productive strategy. This could be done for example by highlighting examples of energy conservation practices observed in others, or emphasising role models within local communities that promote conservation behaviour. Additionally, because energy conservation is a pro-environmental behaviour mostly taking place in the private sphere, the influence of family and household members might be predominant in shifting someone's heating reduction intention. Policy makers could thus also focus on household dynamics in their communication, for example through encouraging people to share their heating behaviour explicitly with other household members.

Second, the modest association between personal moral norms and intention to reduce heating-related energy consumption suggests that targeting people with interventions that focus on increasing personal moral norms will probably not be as effective. Even if people feel morally obliged to conserve more energy, previous research confirms that those values did not affect their actual energy conservation behaviour (Shi

et al., 2019). One explanation might be that VBN Theory is not the most apt theory to predict behaviours that are characterized by a significant personal cost (Abrahamse & Steg, 2009), since in that case, people will not perform a certain behaviour if it is too inconvenient. Lowering the temperature at home is a behaviour change that directly impacts the personal comfort and could be perceived as inconvenient, and hence subdue the influence of personal moral norms. Even though a person might be aware of the positive impact of lowering the temperature, the need for a certain level of personal comfort might overshadow that awareness.

This might also be a possible explanation for the weak association between attitude and intention, since lowering the temperature at home is a control behaviour, which is related to a sense of experienced personal (dis)comfort (Nie et al., 2019; Z. Wang et al., 2011). Even if people have a positive attitude towards lowering their energy consumption, they do not want to give up a certain level of personal comfort in their homes. Indeed, Wang et al. found in their study on household energy-saving behaviour that the discomfort caused by electricity-saving activities had a negative influence on people's energy-saving behaviour (2011). Thus, interventions focusing on increasing moral awareness or attitudes related to lowering one's heating consumption might be less effective because they are overshadowed by certain standards related to personal thermal comfort.

Lastly, we found that PBC has a significant influence on intention, emphasizing the importance of increasing people's perceived capability to alter heating-related consumption patterns. As such, this might include providing practical tools that enable people to analyse and visualize their consumption patterns in a clear and understandable manner. Additionally, complementing those insights with pragmatic and personal tips that are tailored to the specific living conditions of households, can boost their confidence in implementing energy-saving behaviours without compromising on aspects such as personal comfort.

As mentioned, this study was part of the NUDGE project, a larger study encompassing different types of energy-related curtailment behaviours (Conradie et al., 2023). The baseline survey took place before the pilot phase in 2021, while this survey was conducted in 2022. Our findings are broadly in line with the results from the original study, which suggests

that the pilot participants have similar behavioural patterns as those participating in the broader survey. Moreover, we did not find any statistically significant results for pilot location on intention in our model, meaning that there are no disparities across different countries in terms of intention to lower the temperature in winter. Our results confirm the potential of combining the rational (TPB), the socially reactive (PWM) and the moral (VBN theory) path to decision-making to offer a more comprehensive view of energy consumption behaviour change. In this combined behavioural model, the socially-reactive path plays a principal role, while the moral path is the least predictive of heating-related energy behaviour change. Future research could further explore the interplay between these three paths, leading to a theoretical refinement of the relationship between TPB, PWM and VBN theory, as well as exploring alternatives to the moral path that could prove to be more predictive for energy consumption behaviour.

Limitations

It is important to acknowledge certain limitations inherent in our study. Firstly, although the overall adequacy of our model's fit was deemed acceptable, we used two-item measures for several constructs. While three-item measures are preferred to assure the validity of constructs (Eisinga et al., 2013), we made this strategic decision because our research was part of a broader survey examining diverse energy-related behaviours such as improving air quality, boosting self-consumption of renewable energy, or reducing gas usage. Therefore, our survey was quite lengthy and we decided to limit the number of items per construct to mitigate participant fatigue. As a consequence, our model could be perceived as less robust because of these simplifications. Additionally, while most factor loadings, Cronbach's α and Spearman-Brown values of our constructs registered above the conventional thresholds, willingness fell slightly below that threshold with a Cronbach's α of 0.62.

Secondly, this study used a cross-sectional approach, measuring intention to lower the temperature in winter as an outcome variable. Because of practical limitations, it was not feasible to measure actual behaviour in our study. Therefore, it is difficult to draw conclusions concerning the causal pathways predicting actual behaviour changes in energy

consumption. While the intention-behaviour correlation in past research has been substantial (Ajzen, 2011), there are certain conditions that might lower the correlation, such as a lack of compatibility in measurement of intention and actual behaviour, time-related changes and low control over certain types of behaviour (Ajzen, 2020). Additionally, we must consider the influence of confounding variables at the time of data collection, such as people already having a low thermostat settings. While we did not find any significant results when including subjective energy consciousness, a longitudinal study including possible confounding variables would prove useful to test the pathways in the decision-making process and to draw conclusions on actual reduction behaviour.

Lastly, this research used a convenience sample drawn from the pilot pools in the five participating countries, meaning that the sample of this study was considerably smaller than the sample of our baseline study from 2021. Because of that, it is hard to make generalizations on energy reduction intentions. Additionally, our sample consisted of rather young, predominantly male participants, which were recruited partially through technological partners. This implies a risk of participation bias, since participants recruited inherently could be more interested in their energy consumption behaviour and could be more technologically savvy. Future research could take this into consideration by including a more varied and representative sample, diversifying in technological literacy, gender and age.

Conclusion

The findings of our study build on the existing literature on the determinants of people's intention to reduce domestic energy consumption, specifically reducing heating consumption by lowering the temperature in winter. In our study, we approach energy-saving behaviour from a multi-model angle, combining the rational path to decision-making using TPB, the moral path to decision-making using VBN theory, and the socially reactive path to decision making using PWM. The aim of our study was to provide a more comprehensive understanding of heating-related energy behaviour intention and to evaluate potential differences in behavioural intentions among the different pilot studies. Our results emphasize the

primary importance of willingness, prototype favourability and prototype similarity in increasing someone's intention to lower the temperature in winter, as well as the significance of SNs and PBC. These findings suggest that social influences play a prominent role in prediction someone's energy behaviour intentions, with people being influenced by how they perceive other people's heating behaviour, both fictional people and people within their close environments. Additionally, the significant effect of PBC on intention underlines the importance of increasing people's perceived capability to alter heating-related consumption patterns. Finally, our results suggest that the moral path, i.e. VBN theory, is less predictive of personal energy curtailment. Additionally, the association between attitude and intention is rather weak, implying that for heating-related behaviour, people do not want to give up a certain level of personal comfort in their homes. Further research and explorations of alternative frameworks in this domain are recommended.

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Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Emma Martens, Peter Conradie, Stephanie Van Hove, Sabine Preuss, Sabine Pelka, Merkouris Karaliopoulos, Andreas Chitos, Marta Gabriel and Koen Ponnet. The first draft of the manuscript was written by Emma Martens and Peter Conradie and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declarations

Conflicts of interests 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.

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