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Exploring Determinants of Reducing Heating-Related Energy Consumption: Evidence from Five European Countries

Emma Martens[1]*, Peter Conradie[1] Stephanie Van Hove[1], Sabine Pelka[2], Sabine Preuß[2], Merkouris Karaliopoulos[3], Andreas Chitos[4], Marta Gabriel[5], Koen Ponnet[1]

1: imec-mict-UGent,
Miriam Makebaplein 1, 9000
Ghent, Belgium
e-mail: Emma.Martens,Peter.Conradie,Stephanie.VanHove,Koen.Ponnet@UGent.be
2: Fraunhofer Institute for Systems and Innovation Research,
Breslauer Str. 48, 76139
Karlsruhe, Germany
e-mail: sabine.pelka sabine.preuss@isi.fraunhofer.de
3: Department of Informatics, Athens University of Economics and Business,
Trias 2, Athina 113 62
Athens, Greece
e-mail: mkaralio@aueb.gr
4: University of Piraeus, Department of Digital Systems
Piraeus, Greece
email: achitos@unipi.gr
5: INEGI, Institute of Science and Innovation in Mechanical and Industrial Engineering,
Rua Dr. Roberto Frias 400, 4200-465
Porto, Portugal
email: gabriel@inegi.up.pt

Abstract

Efforts to reduce heating-related energy consumption have great potential for overall energy reduction, especially considering the significant contribution of heating to energy usage in Europe. This study examines the factors influencing people's intention to decrease energy usage and involved 363 participants, who were part of a larger European project focused on promoting energy reduction. This article presents a smaller-scale model tested among individuals from 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. To ensure construct validity, we conducted a confirmatory factor analysis, followed by a structural equation model. Our findings show that perceived behavioural control, subjective norms, and attitudes (part of Theory of Planned Behaviour) significantly predict the intent to reduce energy consumption. Additionally, personal moral norms (from the Value Belief Norm Theory) and willingness (from the Prototype Willingness Model) play important roles in explaining the intention to reduce consumption. Our results highlight the practical importance of individuals' perceived ability and their personal moral beliefs to reduce consumption, while positive role models can positively impact willingness to change one's consumption behaviour.

Topics: 2a, 3a
Keywords: energy efficiency, behaviour, behavioural modelling

1. INTRODUCTION AND THEORETHICAL BACKGROUND

Across Europe, heating forms the single highest share of energy consumption at an average of 63%, with Malta's share at 18% and Luxembourg at 82% (Eurostat, 2021). More generally, homes contribute significantly to greenhouse gas emissions, responsible for 20% in the US and 25% in the EU (Goldstein et al., 2020; Jakučionytė-Skodienė et al., 2022), with research by Costa et al. (2013) also estimating that residential and commercial buildings contribute over 30% of CO_2 emissions. While efforts such as home renovation have a significant role to play in reducing energy consumption (Felius et al., 2020), research has also illustrated that occupant behaviour can contribute to energy consumption reductions, for example by lowering temperature settings (Lopes et al., 2012; Steemers & Yun, 2009). As a result, there is an interest in fostering an in-depth understanding of the behavioural factors that contribute to people's intent to reduce their energy consumption generally, and reduction of heating related consumption specifically.
A particularly robust framework to understand behavioural intent is Ajzen's Theory of Planned Pehaviour (Ajzen, 1991) (TPB). It has been applied in a broad range of behaviour (Hardeman et al., 2002), including energy saving (La Barbera & Ajzen, 2021). Nonetheless, the TPB has been criticised, notably because it emphasises rational decision making (Gao et al., 2017). To heed these criticisms, the TPB has frequently been extended with additional variables (Perugini & Bagozzi, 2001) or additional behavioural models (Rivis et al., 2006). Given this, we have developed a behavioural model that extends the TPB to also capture socially reactive behaviour through the Prototype Willingness Model (PWM) (Gerrard et al., 2008) and the moral path to behaviour through the Value-Belief-Norm (VBN) Theory (Steg et al., 2005; Stern et al., 1999). Below we expand further on the use of these theories.

1.1 Theory of Planned Behaviour (TPB)

Centrally, Ajzen proposes that three variables are predictive of someone's intent to engage in an activity: attitude, perceived behavioural control (PBC) and subjective norms (SNs). Attitude can be seen as someone's appraisal of a particular behaviour, with people viewing the behaviour positively being more likely to also engage in that behaviour. Perceived behavioural control can be seen as the self-perceived ability people feel they have to engage in that behaviour and is positively associated with intent. Finally, subjective norms can be defined as someone's beliefs about what others close to them think of the behaviour. The TPB has seen wide application in a variety of domains (Hardeman et al., 2002) and is a very robust theory of human behaviour. Examples include purchasing of sustainable housing (Judge et al., 2019), recycling behaviour (Tonglet et al., 2004) and energy reduction (La Barbera & Ajzen, 2021). Given this, we formulate the following hypothesis:
Positive attitudes towards energy reduction (**H1**), PBC (**H2**) and SNs (**H3**) are positively related to the intent to reduce energy consumption by lowering the temperature in winter.

1.2. Prototype Willingness Model (PWM)

An additional model of interest is the PWM (Gerrard et al., 2008). The PWM was originally developed to explore socially reactive paths to decision making, most prominently within the domain of health care and risk behaviour. While the PWM had an initial focus on adolescents, Gerard et al. (2008) emphasised that the model could also be applicable for adults. Additionally, despite its focus to understand risk and health related behaviours, it has also been used within the domain of sustainability (Ratliff et al., 2017). Of extra interest is the PWM's application in tandem with the TPB (Rivis et al., 2006). In brief, the PWM proposes that the willingness to engage in an activity is predicted by favourability of prototypes and the similarity of prototypes. These variables refer to how positively individuals perceive someone participating in an activity (prototype favourability) and how closely they perceive themselves in resemblance (prototype similarity) to the person engaged in that activity. The combined impact of prototype favourability and prototype similarity shapes an individual's willingness to perform an activity. We formulate the following hypothesis:

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

1.3. Value-Belief-Norm Theory (VBN)

We also extend our behavioural model with VBN Theory, that focuses on moral and personal norms related to sustainable behaviour. Stern and colleagues (1999) found that people are more likely to engage in sustainable behaviour if they feel a moral obligation to do so. This means that personal moral norms, or beliefs about what is right and wrong, can predict sustainable behaviour.

Given its prominence within the domain of sustainability, there is robust evidence of the value and predictive power of VBN Theory to predict reduction in energy consumption (Wang et al., 2018), but also intention to use renewable energy (Fornara et al., 2016) or behaviours related to climate mitigation (Zhang et al., 2020). Research by Steg et al. (2005) also highlighted a causal chain, proposing that people first need to be aware of the consequences caused by their behaviour, before they feel (jointly) responsible for energy problems. In turn, ascription of responsibility is predictive of pro-environmental personal norms, which finally predicts intent. In sum, we thus propose:

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

H8: Ascription of responsibility is positively associated with pro-environmental personal norms.

H9: Pro-environmental personal norms are positively associated with intent to reduce energy consumption by lowering the temperature setting.

2. METHOD

2.1. Research context, instrument development and data gathering.

This research is situated within a larger project, NUDGE (European Commission, 2020), where, as part of an effort to understand the intent to reduce energy consumption, we developed a behavioural model that considers the aforementioned pathways of decision-making (socially reactive, moral or rational) and how it can predict reduction of heating related energy consumption. This led to the development of a survey and gathering data from 3098 people in 29 countries within Europe. The results found support for our three theoretical models discussed earlier (Conradie et al., 2023), and were also used to develop specific energy consumption profiles based on differences with regards to energy saving behaviour (Karaliopoulos et al., 2022), as well as forming the base of behavioural interventions evaluated later during the project (Burkhardt et al., 2022).

The goal of this study is to assess whether the participants in our pilots differ with regards to their behavioural intent, keeping in mind the results from our first, general study. To do so, we developed a smaller pilot-specific survey that was distributed among each of the pilot locations in the projects. Each pilot had a slightly different focus, with each pilot-specific survey tailored to the goals within the pilot. In brief, our Belgium pilot focused on the impact of intergenerational learning on energy use, while in Portugal the focus was on improving air quality and reducing energy consumption. Germany and Croatia focused on increasing self-consumption of energy, and the Greek pilot focused on reducing gas consumption. However, across all pilots, we measured the specific intent of participants to lower the temperature setting in winter through a survey. Although the scope of the pilots differed from one another, the operationalization of the measurements for this study are identical across all pilots.

Scale development was discussed at-length in the original article (Conradie et al., 2023), but in brief, we developed the items applied for each of the models by re-appropriating the questions from the models in question and modifying them for the purpose of this study. For the TPB, this included items by Ajzen (1991), developed specifically to assess energy reduction (La Barbera & Ajzen, 2021). For the PWM, we relied on Gerrard et al. (2008), but also drew from work in different domains (Van Gool et al., 2015), while for VBN we re-appropriated items from Abrahamse & Steg (2009).

	Belgium	Croatia	Germany	Greece	Portugal
Number of participants	58	82	105	33	85
Percentage male	53%	93%	88%	80%	51%
Mean age (2023)	45	49	58	36	41
Mean intent to reduce consumption	3.81	3.59	3.40	3.62	3.80

Table 1: Age, gender and mean intent to reduce heating related consumption across pilots.

The survey was originally developed in English and subsequently translated into the native languages used in the pilots: German, Croatian, Dutch, Portuguese and Greek. Native speakers within the consortium assisted with the translation. We used a backtranslation approach (Brislin, 1970) where we first translated the items to the native language, after which they were translated back to English. If differences with the original English items were found, this process was repeated until a satisfactory translation was achieved. A complete list of items can be found in table 2. All statements are measured using a 5-point Likert scale, except for attitude, which was measured on a 7-points semantic scale. We retained 363 participants across our pilots who fully completed the questions in our behavioural model. Our sample contained more men than women (73.83%). The mean date of birth was 1975 (i.e., 48 years old), while mean intent was 3.62 (on a 5-point Likert scale).

Latent variable	Item id	α	Factor Loadings	Item text
Intent	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	0.82	0.75	Disadvantageous - advantageous
	ATT_2		0.95	Foolish – wise
Perceived Behavioural Control	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_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	0.75	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	0.84	I take joint responsibility for the depletion of energy resources.
	ASCR_RESP_2		0.93	I feel jointly responsible for the greenhouse effect.
Awareness of Consequences	C_AWARE_1	0.69	0.84	Energy conservation contributes to a reduction of global warming.
	C_AWARE_2		0.63	The increasing energy demand 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	0.60	0.60	You lower the temperature setting in all unused rooms when you are at home all day.
	WILL_2		0.72	You lower the temperature setting when you leave home.

Table 2: Latent variable, item id, Chronbach's α, factor loadings and item text for all observed variables

2.2. Analytic approach

We followed a common analytical approach for structural equation modelling, which includes a brief preliminary analysis of key variables (one-way analysis of variance, t-tests and Pearson's correlation analysis), followed by establishing a measurement model and subsequently a structural equation model (Anderson & Gerbing, 1988). Our measurement model serves to determine whether the observed variables (i.e., the questions or items that we will ask participants) reliably reflect the proposed latent variables (i.e., the constructs that we are trying to measure). To determine fit, we used a variety of indices, as suggested by Schreiber et al. (2006). First, Tucker Lewis index (TLI), ranging from 0 to 1.00, with values above 0.9 indicating good fit. Comparative fit index (CFI) similarly has a range from 0 to 1.00, with values above 0.9 indicating good fit. We combine this with the root mean square error of approximation (RMSEA), which also ranges from 0 to 1.00, with values below 0.05 indicating good fit and values from 0.06 to 0.08 indicating adequate fit. Threshold for statistical significance was set at $p = 0.05$.

3. RESULTS

3.1. Preliminary analysis

Average intent to reduce heating related energy consumption was 3.62 ($SD = 1.00$). We found a difference in intent across the pilots ($F(4, 358) = 2.601$, $p = 0.036$). A post-hoc Tukey test shows that the only statistically significant difference was between Portugal and Germany, with German intent the lowest. In terms of differences between gender, a Welch two-sample T-test suggests that no differences could be found between gender and intent ($t = 1.946$, $p = 0.053$).
Our Pearson correlation analysis finds statistically significant correlations for all the hypothesised relationships between intent on the one hand and attitude, PBC, SNs, personal moral norms and willingness on the other, indicating preliminary support for the predictive power of our three behavioural models on intent (see table 3).

3.2. Confirmatory Factor Analysis and Structural Equation Modelling

In line with our original study, we removed items with factor loadings below 0.4 and allowed error co-variance between similarly phrased items. This resulted in a satisfactory model fit: TLI

= 0.922, CFI = 0.945, RMSEA = 0.061, with error co-variance allowed between ASCR_RESP_1~~ASCR_RESP_2. All indices meet minimum fit requirements, and as a result, we proceed with our SEM.

As mentioned earlier, we found statistically significant differences in intent across the pilots between Portugal and Germany (in our Tukey post-hoc test). To assess whether this has an impact on our results, we performed an analysis using pilot locations as categorical predictors, regressed on intent. Germany was used as reference category. Fit was poor (TLI = 0.821, CFI = 0.850 and RMSEA 0.081) and our results show that pilot location has no statistically significant impact on intent when included in our overall model. Given this, we proceed with removal of our pilots as predictors. Consequently, our model fit improves with TLI = 0.904, CFI = 0.924 and RMSEA = 0.067**.** We proceed with this model.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Intent (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)	0.30**	0.27**	0.22**	0.12	0.38**	0.37**			
Prototype Favorability (7)	0.46**	0.40**	0.40**	0.28**	0.45**	0.37**	0.34**		
Prototype Similarity (8)	0.58**	0.42**	0.42**	0.43**	0.45**	0.30**	0.22**	0.44**	
Willingness (9)	0.52**	0.38**	0.33**	0.31**	0.36**	0.22**	0.20**	0.35**	0.45**

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

Examining our results more closely, we see support for all hypotheses. Firstly, within the TPB, attitude ($\beta = 0.159$, $p = 0.001$), PBC ($\beta = 0.214$, $p < 0.001$) and SN ($\beta = 0.257$, $p < 0.001$) are all predictive of intent. Second, willingness, as part of the PWM, is similarly associated with intent ($\beta = 0.433$, $p < 0.001$), with both prototype similarity ($\beta = 0.499$, $p < 0.001$) and prototype favourability ($\beta = 0.255$, $p < 0.001$) being associated with willingness. Lastly, within VBN-theory, we find awareness of consequences to be associated with ascription of responsibility ($\beta = 0.888$, $p < 0.001$), ascription of responsibility to be predictive of personal norms ($\beta = 0.878$, $p < 0.001$), and personal norms to be significantly associated with intent ($\beta = 0.099$, $p = 0.040$). Overall, our model was able to predict 72% of variance for intent, 77% for personal norms, 78% for ascription of responsibility and 45% for willingness.

4. LIMITATIONS AND DISCUSSION

Before reflecting more on our results, we note some limitations. First, while the overall

model fit was satisfactory, we used two-item measures for many constructs. This was a deliberate choice in order to reduce participant fatigue, given that our study took place within the context of a much larger survey that also looked at specific behaviours including air quality (Gabriel et al., 2023) and self-consumption of electricity (Pelka et al., 2023). As a result, our overall model could be viewed as less robust. We also note that reliability for Willingness (as part of the PWM) was below the customary threshold of Cronbach α of 0.70 at 0.60.

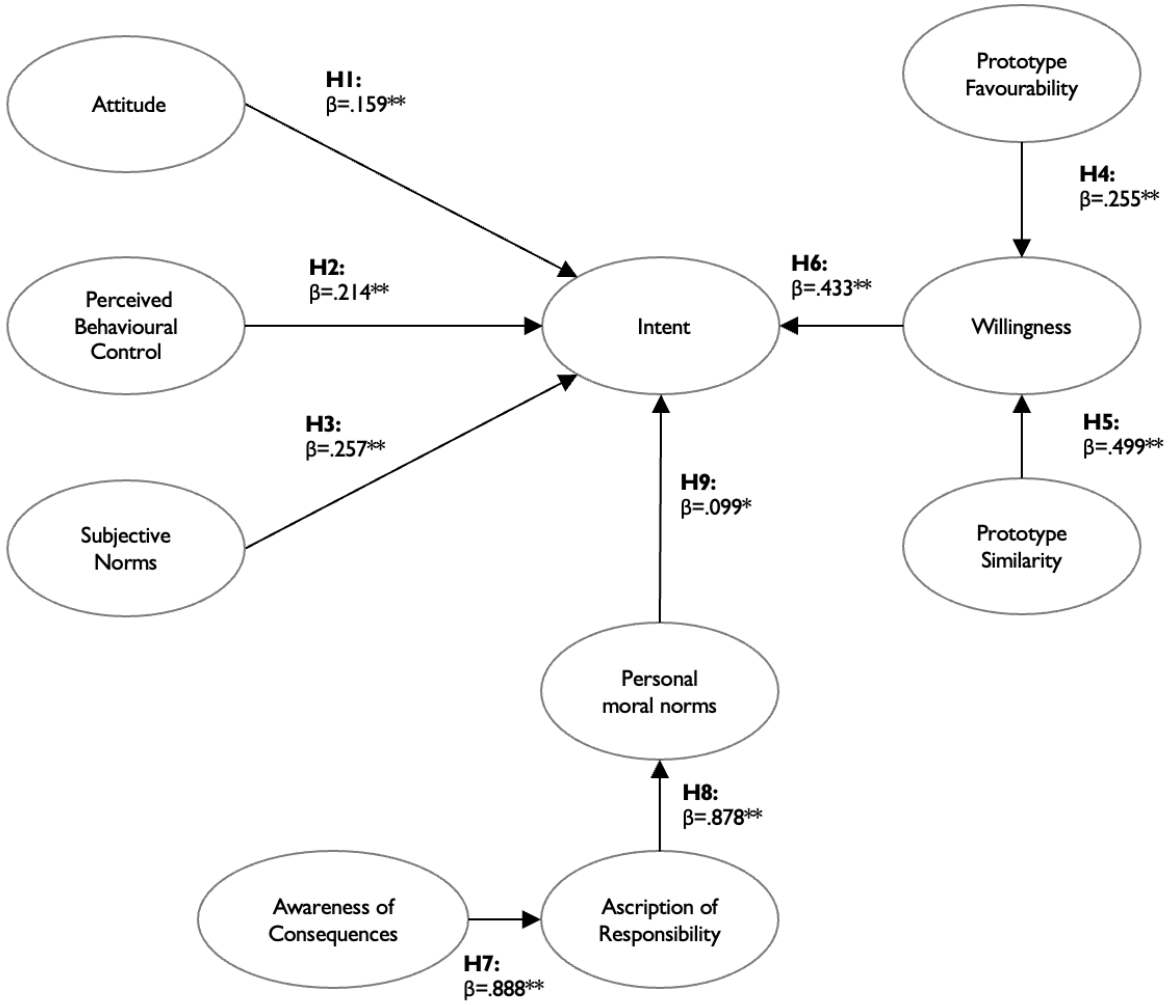

Figure 1: Results from our SEM analysis ($p < 0.05$ = *; $p < 0.01$ = **); TLI = 0.904, CFI = 0.924 and RMSEA = 0.067

Nonetheless, we find support for all hypotheses, with explained variance for intent at 72%. For the TPB, we see support for H1, H2 and H3. However, both PBC and SNs appear to have stronger relationships with intent than attitude.

H4, H5 and H6 were part of the PWM and are also supported, with both prototype

favourability and prototype similarity being associated with willingness, and willingness being associated with intent. Moreover, willingness appears especially strongly associated with intent, which suggests that, at least within our sample, socially reactive decision making is a strong predictor of intent to reduce heating related consumption.
However, our VBN-theory implementation shows less promise. While reaching a level of statistical significance at $p = 0.04$, the association between personal moral norms and intent (H9) is comparatively weak. One reason for this may be that VBN-theory might be less suited to explain behaviour with a high personal cost, as also noted by Abrahamse & Steg (2009). Indeed, lowering the temperature in the home directly influences one's personal comfort. Nonetheless, support for the association between awareness of consequences and ascription of responsibility (H7) and the association between ascription of responsibility and personal moral norms (H8) is strong.
Compared with our original study, we find broadly similar results, suggesting our pilot participants do not diverge radically from the participants in our more general survey. Notable differences include a much stronger relationship between willingness and intent ($\beta = 0.433$, $p < 0.001$) (as part of PWM). VBN-Theory's support was slightly stronger compared to the original study, but the statistical significance remains weak compared to the other applied theories.
From a policy standpoint, our findings highlight the significance of decision-making influenced by social reactions, particularly in our support of the PWM. Prioritizing the favourability of prototypes proves to be a valuable method for increasing willingness. Additionally, the relevance of SNs underscores the idea that others' opinions matter. This emphasizes the importance of incorporating SNs into policies, such as highlighting energy conservation behaviours observed in others.
Furthermore, PBC's impact on intent also points towards better understanding of the perceived ability to reduce heating, which may include providing better tools which should allow better insight into consumption, but also helping people visualise and contextualise energy saving (i.e.: in money saved or reduced emissions). Other efforts here may include providing practical tips to households in order to strengthen their PBC over energy reduction.
Overall, our results contribute to existing work exploring the determinants of intention to reduce energy consumption. We emphasise the importance of both SNs and PBC on intent, while willingness also appears to have a strong association. Our evidence for the use of VBN-theory is, however, weak, arguing against its use to predict personal energy curtailment.

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