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Energy-efficient heating appliance behavior change

The role of green self-identity

Joana Paisana Pires Costa das Neves

Dissertation presented as the partial requirement for obtaining a Master's degree in Information Management

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ENERGY-EFFICIENT HEATING APPLIANCE BEHAVIOR CHANGE: THE ROLE OF GREEN SELF IDENTITY

by

Joana Paisana Pires Costa das Neves

Dissertation presented as partial requirement for obtaining the Master's degree in Information Management, with a specialization in Knowledge Management and Business Intelligence

Advisor: Prof. Dr. Tiago André Gonçalves Félix de Oliveira

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DEDICATION

Aos meus pais, agradeço o apoio, ajuda e paciência incondicional. Só com o vosso apoio consegui alcançar os meus objetivos e ainda ir mais além.

Mana, obrigada pelo teu companheirismo e por me ajudares a percorrer este percurso, sempre lado a lado.

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ABSTRACT

Nowadays, the concern with the environment is increasingly important, with energy being one of the sectors that have the highest impact on the environment. As such, the energy consumed by households is an area that has repercussions when it comes to reducing energy consumption. This consumption has different sources, for instance, the heating appliance. With the objective of reducing the energy consumed, this study integrates five factors emerged from the literature review to explain the change to an energy-efficient heating appliance (EEHA), namely: savings, label, operation and maintenance, co-benefits, and green self-identity, as well as green self-identity as moderator. Based on a sample of 1136 responses, this work reveals the significance of all factors for the attitude on heating equipment use, and all the factors excepting the direct effect of co-benefits for the behavior intention to change to an EEHA. The moderator influence of the green self-identity was also found: between the label and both behavior change, i.e., attitude on heating equipment use and behavior intention to change to an EEHA; and also between the operation and maintenance and both behavior change.

KEYWORDS

Efficient energy; appliances; energy-efficient heating appliance (EEHA); green self-identity; change behavior model

RESUMO

Atualmente, a preocupação com o meio ambiente é cada vez mais relevante, sendo a energia um dos setores que mais impactam o meio ambiente. Sendo assim, a energia consumida pelas habitações é uma área que tem importância na tentativa de redução do consumo de energia. Este consumo tem diferentes origens, por exemplo, o aparelho de aquecimento. Tendo como objetivo a redução da energia consumida, este estudo integra cinco fatores provenientes da revisão da literatura para explicar a mudança para um aquecimento energeticamente eficiente (AEE), nomeadamente: poupanças, etiqueta energética, operação e manutenção do equipamento, co-benefícios e auto-identidade verde, sendo que este último atua também como moderador. Com base numa amostra de 1136 respostas, este trabalho revela significância de todos os fatores para a atitude no uso do equipamento de aquecimento, e todos os fatores, exceto o efeito direto dos co-benefícios para a intenção de mudar para um AEE. A influência moderadora da auto-identidade verde também foi encontrada: entre a etiqueta energética e ambos os fatores de mudança de comportamento, ou seja, atitude sobre o uso do equipamento de aquecimento e intenção de mudança para AEE; e entre a operação e manutenção do equipamento e ambos os fatores de mudança de comportamento.

PALAVRAS-CHAVE

Energia eficiente; equipamentos aquecimento energeticamente eficiente (AEE); auto-identidade verde; modelo de mudança de comportamento

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LIST OF ABBREVIATIONS AND ACRONYMS

EEHA energy-efficient heating appliance

NZEBs near-zero energy buildings

1. INTRODUCTION

Currently, with environmental problems more present, it is indispensable to take measures that contribute to their reduction. One of the sectors that most contribute to this environmental situation is energy. This sector is a clincher for the good functioning of a country and to boost its economy [1]. As such, it is necessary to find a balance between the amount of energy consumed and the environmental problems caused by the abuse of energy consumption and energy sources that are not environmentally friendly. One solution will be to use efficient energy, that is, to change appliances that use resources that are inappropriate for the environment, for more efficient energy sources. In fact, efficient energy (which includes the concept of green energy), has gained special attention from researchers because it is one of the most important and effective means for reducing environmental problems [2].

In this context, the concept of energy-efficient heating appliances (EEHA) emerges. It is imperative to meet the European policies defined in terms of energy in buildings in order to meet the goal of near-zero energy buildings (NZEBs) [3]. Thus, a central point will be the heating equipment of buildings. In order to achieve the desired results, the change must start with the energy consumed by households, namely by household appliances [4]. Energy consumption has increased intensely in buildings [5], with household appliances representing a large percentage of that consumption [6,7]. Also, we can affirm that residential space heating systems are responsible for a large fraction of the energy demand of private households [8]. So, it is of extreme relevance to take some actions in that field. It is stated that behaviors and attitudes must be modified in order to ensure a sustainable energy future [9]. A first step toward that change can be through the change to an EEHA (e.g. heat pump).

To the best of our knowledge, the literature even already containing some studies related to the change of appliances, few are those that integrates in a single model the wide variety of factors that influence/predict the change to energy efficient heating equipment. Moreover, are even less those studies that try to integrate moderating effects in the change of EEHA. Thus, this work fills two main gaps in the literature: (1) it explores more deeply the consumer motivations to change to an EEHA; (2) it uses a method that allows estimating the model with two dependent variables (attitude on heating equipment use and behavior intention to change to an EEHA). This investigation will allow us to have a holistic view of EEHA. Besides the importance of identifying the characteristics that can influence consumers to change to an EEHA, it is also relevant to understand some moderator effects. Sparks and Shepherd [11], says that self-identity, related to the green consumer, will contribute to predicting consumer behavior. So, it will be relevant to study how the ecological entity of each one can affect the change to an EEHA. As such, here, we want to understand how this green self-identity moderates the relationships between the influencing factors and the behavior change. Thus, this work has two main objectives: (1) create a unified research model that integrates the various factors that lead consumers to change to an EEHA; (2) understand the moderator effect of the green self-identity on the factors that explain the change to an EEHA by the consumers.

Consequently, this study presents threefold contributions. Firstly, it presents the direct and indirect effects of the factors that influence the change to an EEHA, allowing us to have a holistic view of the EEHA. Secondly, it investigates the moderator effects of the green self-identity in the relationship between the factors identified and the behavior change to an EEHA. Finally, the results presented will allow creating effective policies and marketing programs that motivate consumers to change to an

EEHA and adopt and use energy more efficiently. More specifically, this study can help energy organizations, energy consultants, or even fabricants and vendors of heating equipments.

This study is structured as follows. Section 2 provides a theoretical background about EEHA and green self-identity and contains the literature review. Section 3 provides the research model and hypotheses. Section 4 presents the methodology used and describes the data, explaining the survey crated and characterizing the sample obtained. Section 5 contains the data analysis and results, where it is explained the partial least square technique (PLS), used to run the research model. Also is analysed the measurement model, where it is verified and confirmed the internal consistency, convergent reliability and discriminatory validity of all constructs and the non-existence of collinearity. This section also presents the structural model, where is analysed the explanation capacity of the model and the significance of the hypotheses (about 75% were supported). Section 6 presents a discussion of the results, as well as some limitations and future research. In this section, it is provided some recommendations to increase the adoption of EEHA and is given some encouragement to expand the research to other countries. Finally, Section 7 provides a brief conclusion of the work.

2. LITERATURE REVIEW

2.1. ENERGY-EFFICIENT HEATING APPLIANCE (EEHA)

An EEHA is an equipment that is responsible for the space heating of a household or domestic water heating, or it can be a combination of both [12]. This appliance contributes to the large energy consumption that the building sector represents. This sphere accounts for about 40% of final energy consumption in the European Union, [13,14], and releases about 30% of the world's greenhouse gases [15]. As such, the building sector is one of the most responsible for the environmental problems we witness. More specifically, heating appliances are the largest end-use for energy in Europe and North America [13]. Therefore, heating in the residential sector is one of the most relevant and impacting areas in terms of energy use [16]. As such, it is precisely this sector that has tremendous potential for energy savings [17].

2.2. THE CONCEPT OF GREEN SELF-IDENTITY

Self-identity is characterized as being the group of principles that each person has, and that can induce the performance of some actions [18]. Following that logic, an individual is considered to have a green self-identity when it is identified with environmentally friendly values, and it encouraged them to take environmental thinking attitudes and purchase green products [19]. Carfora et al. [18], refers that pro-environmental self-identity can be important to predict intentions and behavior, and can also moderate the effect of perceived behavior control on intentions. In that way, we understand that environmental self-identity can be considered a factor that influence behavior (e.g., change heating system [20,21]), but can also act as a moderator.

2.3. DRIVERS EMERGING FROM THE LITERATURE

Following the existing literature about EEHA, self-identity and also the change in behavior towards sustainable appliances, we identified the most relevant, consistently significant, and most cited factors. (1) Concerning economic aspects, various studies include these characteristics as a critical aspect to explain the change of appliances, namely the costs as a barrier or savings as a motivation. For example, Niamir et al. [10] concluded that some individuals, mainly those with an unsatisfied economic situation, are more likely to change appliances to try to save money. Gaspar and Antunes [4] include energy-saving appliances as a predictor of choice, with long-term savings being one frequent concern when choosing the appliance to purchase since consumers are able to obtain lower energy consumption with the use of an efficient heating appliance. (2) The aspects related to the importance of the energy label can also influence consumers when making decisions about household appliances [22]. For example, Wang et al. [23] affirm that the energy efficiency label information has a great impact on consumers' intention to purchase household appliances that allow them to save energy. As such, the energy efficiency class of appliances is considered as frequent characteristic in the appliance's choice [4]; (3) The aspects related to the work required in the equipment under analysis are also a commonplace factor used in this type of studies. Sopha and Klöckner [16] include the operation and maintenance work that heating systems require as a potential factor in the decision to adopt a heating

system. So, the extra work that this equipment may demand and also the level of difficulty to use them, i.e., the ease of use, are factors identified as influencers when choosing a residential heating system [8,24]; (4) Many studies of this theme also considered as relevant factors, the comfort, aesthetics, safety, and value that the substitution of an appliance could bring. For example, Hrovatin and Zorić [17] include thermal comfort improvements as a determinant to predict energy-efficient home retrofits. Michelsen and Madlener [8] have a component designated as comfort considerations to explain what can influence homeowners to decide between residential heating systems, where one of the topics is related to the value of the house and the possibility of being more independent of certain energy sources. Also, Gaspar and Antunes [4] include safety as an aspect to take into consideration when choosing an appliance. Sopha and Klöckner [16] acknowledge aspects related to indoor air quality and supply security to explain the adoption and diffusion of heating systems. All of these characteristics, known as co-benefits, relate to either positive or negative benefits that the replacement of an appliance can bring to individuals and a dwelling house [25]; (5) Other studies also mention the importance of environmental awareness [17,26] and green consumerism [11] to explain the choice of appliances. Michelsen and Madlener [8] include an aspect related to the contribution to the environment that each individual can make when choosing a residential heating system. Gaspar and Antunes [4] also refer that a concern with environmental problems is a relevant factor when consumers choose appliances.

Table 1 provides a summary of the factors identified in previous studies to explain the change of appliances (namely, heating ones). The factors found are summarized in: (1) savings (energetic and monetary) including in this way the economic aspects [4,8,10,17,26–28]; (2) label, i.e., energetic class of the appliance [4,10,22,23,26]; (3) operation and maintenance work that the new appliance may require [4,8,16,24,28]; (4) the set of factors related to the comfort, aesthetics, safety, and value of the home which are denominated as co-benefits, that the change to an efficient appliance can bring [25,29,30] and; (5) green self-identity, which is the consumers' environmental awareness [4,8,10,11,17,20,23,24,26,28]. The creation of these categories was based on the meaning of each factor in order to harmonize different synonyms for the same factor (section 3 describes in more detail each factor created, based on the literature).

Title	Factors					Source
	Savings	Label	Operation and maintenance work	Co-benefits	Green self-identity	
Personal values, green self-identity and electric car adoption					X	[20]
Benefits from energy related building renovation beyond costs, energy and emissions				X		[29]
Impact of co-benefits on the assessment of energy related building renovation with a nearly-zero energy target				X		[25]
Energy efficiency and appliance purchases in Europe: consumer profiles and choice determinants	X	X	X	X	X	[4]

Determinants of energy-efficient home retrofits in Slovenia: the role of information sources	X			X	X	[17]
An empirical analysis on awareness and intention adoption of residential ground source heat pump systems in Greece			X	X	X	[24]
An adopter-centric approach to analyze the diffusion patterns of innovative residential heating systems in Sweden	X			X		[27]
Adoption of innovative heating systems—needs and attitudes of Swedish homeowners				X		[31]
Homeowners' preferences for adopting innovative residential heating systems: a discrete choice analysis for Germany	X		X	X	X	[28]
Motivational factors influencing the homeowners' decisions between residential heating systems (an empirical analysis in Germany)	X		X	X	X	[8]
Demand-side solutions for climate mitigation: bottom-up drivers of household energy behavior change in the Netherlands and Spain	X	X			X	[10]
The influence of eco-labeling on consumer behaviour – results of a discrete choice analysis for washing machines		X				[22]
Psychological factors in the diffusion of sustainable technology: a study of Norwegian households' adoption of wood pellet heating			X	X		[16]
Assessing the role of identification with "green consumerism"					X	[11]
Policy implications of the purchasing intentions towards energy-efficient appliances among China's urban residents: do subsidies work?	X	X			X	[26]
Purchasing intentions of Chinese consumers on energy-efficient appliances: is the energy efficiency label effective?		X			X	[23]

Table 1. Some studies related to the phenomena of our work

However, in our understanding, these variables, although relevant to explain the phenomenon in question, are not sufficient to explain this complex phenomenon of behavior change. Thus, we realize that what has been accomplished in the literature, so far, does not capture the importance of the environmental factor as a moderating effect of relationships. Also, does not exist a single integrative model that captures all of this factors (including the moderator effects).

3. RESEARCH MODEL

We propose an integrative model of five factors emerging from the literature to explain EEHA change behavior. The first one is constituted by the savings, and it refers to the potential energy and monetary savings that a consumer can have when deciding to change to an EEHA. The second factor refers to the energetic label of the equipment that has information about its energetic class. The third factor includes the work with the appliance, i.e., operation and maintenance work that can be required. The fourth factor is the co-benefits that include the aspects related to comfort, aesthetics, safety, the value of the home, and independence of energy price fluctuations that a change of appliance can bring. Finally, the fifth group is the green self-identity, which reflects the level of environmental concern that each person has. To understand the role of green self-identity, this work proposes that the green self-identity will have a direct impact in the change to an EEHA, but will also moderate the other factors. The number of elements that constitute the household [36], the average household income (monthly) [36], and the number of children in the household [37] were used as control variables. Figure 1 presents the research model of behavior change to an EEHA.

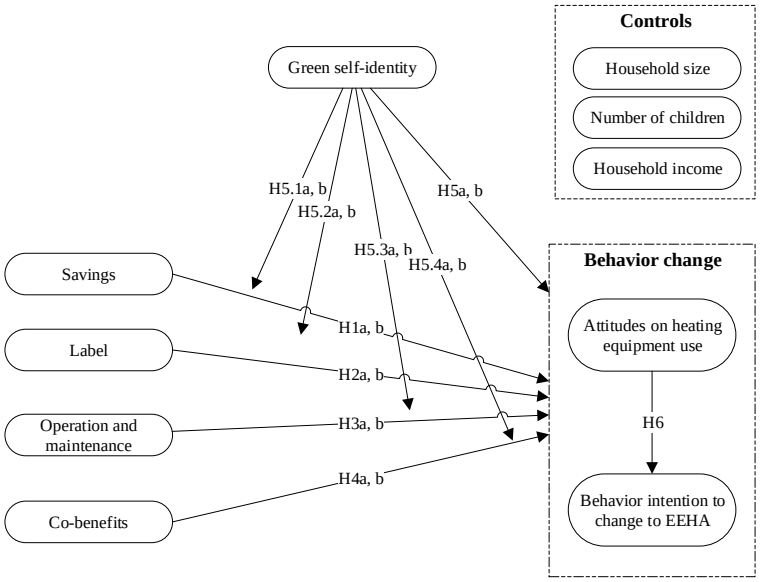

Figure 1. Research model of behavior change to an EEHA

Following, we present the hypotheses of the research model.

The savings corresponds to the monetary and energy an individual can save if he decides to change to an EEHA. Following the work of Gaspar and Antunes [4], the majority of consumers value the savings that they can obtain in the long term due to the fact that they are able to achieve a lower energy consumption with the use of an efficient heating appliance. Michelsen and Madlener [28], also conclude that energy savings are one of the principal factors in the homeowner's decision-making process to adopt a new innovative residential heating system (referring to EEHA). Thus, it is expected that the savings that the consumer can obtain when changing to an EEHA can motivate them actually to change. In that way, savings will have a positive impact in the change to an EEHA:

H1. Savings positively influence the: a) attitude on heating equipment use; b) behavior intention to change to an EEHA.

The label construct represents the level of awareness that consumers have about the energy label of the equipment, which has information about its energetic class. Some papers, such as Gaspar and Antunes [4], state that the majority of consumers pay attention to the energy label and its information and affirm that this factor can be considered moderately in appliance choice. Also, Wang et al. [23], conclude that the greater the consumer awareness of energy efficient labels, the more they will intend to purchase energy-saving household appliances. Sammer and Wüstenhagen [22] suggest that people associate the energy label as a signal of quality, which can motivate them to acquire some energy-efficient products. It also confirms that the energy label positively influences the decision of consumers when buying household appliances. As such, it is expected that the energetic label takes a positive role in influencing consumers to change to an EEHA:

H2. Label positively influences the: a) attitude on heating equipment use; b) behavior intention to change to an EEHA.

Regarding operation and maintenance, this factor refers to the work that the operation and maintenance of an EEHA can give. Some studies suggest that the effort linked to the operation and maintenance (ease of use) of heating systems can influence the decision of consumers when choosing between residential heating systems [8]. In fact, consumers are less likely to save energy and change their behavior towards energy use if that involves high effort costs [32]. In that way, the fact that the installation and maintenance of the new equipment can burden individuals can be seen as a factor to not change to an EEHA. Thus, it is expected that this factor will have a negative effect in the change to an EEHA:

H3. Operation and maintenance negatively influence the: a) attitude on heating equipment use; b) behavior intention to change to an EEHA.

The co-benefits factor represent benefits that the change to an EEHA can bring, namely related to the level of comfort, air quality, noise and aesthetics of the dwelling, but also, in more economic terms, related to the level of exposure to energy price fluctuations and the value of the house. These factors were searched in the literature [4,8,15,17,25,29,30], and it was concluded that those, namely related to the thermal comfort, independence of energy prices, and the appliance aesthetics, are relevant factors that can motivate consumers to choose an appliance [4,17,28]. It is therefore expected that the co-benefits will have a positive effect in the change to an EEHA:

H4. Co-benefits positively influence the: a) attitude on heating equipment use; b) behavior intention to change to an EEHA.

The green self-identity factor reflects the level of environmental concern that each person has and, for that reason, can encourage the change to an EEHA. Many studies consider environmental awareness as one of the most contributing factors that incentivize the purchase of energy-efficient appliances, i.e., EEHA [24,26]. Generally, individuals who already have environmentally-friendly behaviors in some areas are likely to think about extending this behavior to be more consistent in their actions and choose more eco-friendly appliances, i.e., EEHA [4]. Thus, we hypothesize that this factor will have a positive impact in the change to an EEHA:

H5. Green self-identity positively influences the: a) attitude on heating equipment use; b) behavior intention to change to an EEHA.

Although previous studies reveal some primary importance of environmental awareness that each individual has when making decisions, namely changing their heating appliance, there are no studies that evidence the possibility of this factor moderating the relations that other factors (savings, label, operation and maintenance and co-benefits) may have in changing to an EEHA. However, some papers study the moderating effect of environmental awareness but in other contexts, namely, to try to understand how the environmental awareness of each consumer can moderate the behavior intention to choose certified hotels or even restaurants [33,34]. These studies verify that the higher the environmental consciousness of consumers, the greater the effect of the factors that positively influence the behavior intention (to choose certified hotels or revisit a restaurant). Thus, in this work, we decided to make an analogy with these studies and changed the context to EEHA.

Changing over to an EEHA is considered an environmentally friendly decision. As such, usually more environmentally concerned consumers will be more likely to take action in favor of the environment and, in that way, will be more likely to change to an EEHA [26] in order to satisfy their personal values and be coherent with their beliefs. Thus, we will test not only the direct effect of green self-identity but also the moderating ones. Consumers with higher environmental consciousness are more likely to consider the environmental issues when considering other factors like savings, or label, to change their heating appliance than those who do not have that awareness. In that way, and based on the conclusions of other studies, we expect that the green self-identity factor can moderate the EEHA change process:

H5.1. Green self-identity moderates the relationship between the savings construct and the: a) attitude on heating equipment use; b) behavior intention to change to an EEHA.

H5.2. Green self-identity moderates the relationship between the label construct and the: a) attitude on heating equipment use; b) behavior intention to change to an EEHA

H5.3. Green self-identity moderates the relationship between the operation and maintenance construct and the: a) attitude on heating equipment use; b) behavior intention to change to an EEHA.

H5.4. Green self-identity moderates the relationship between the co-benefits construct and the: a) attitude on heating equipment use; b) behavior intention to change to an EEHA.

In this work, we also use attitude on heating equipment use as a construct that can explain behavior intention to change to an EEHA. If my attitude is considered positive, then the behavior intention would also be positive [35]:

H6. Attitude on heating equipment use positively influences the behavior intention to change to an EEHA.

4. METHODS

4.1. MEASUREMENT

In order to perform this work, an online questionnaire was created. We carried out a selection of the variables and respective items to be included in the survey, based on a literature review. In that way, some questions were adapted from the literature to be consistent with the topic. Table 2 includes the items that formed the survey, as well as the corresponding constructs and sources (the survey applied the seven-point Likert scale). A pilot survey was launched, and we obtained approximately 40 responses. Subsequently, this same survey was improved based on the feedback from some specialists in the area, namely energy related organizations (e.g. ADENE, OCU, DECO). Based on their comments, we rewrote some of the items to ensure that each item are equally perceived by the respondents. Thus, after these steps, the final survey was obtained with clear questions.

Construct	Items	Sources
Savings (S)	S1. I receive a subsidy to finance the replacement S2. I am aware of the total energy savings over the EEHA lifetime S3. I am aware of the total monetary savings over the EEHA lifetime	[28]
Label (L)	L1. The energy label is important in the decision of buying a heating appliance L2. When I buy a heating appliance, I pay attention to the energy label L3. I am more willing to buy a heating appliance with an efficient energy class (above C, i.e., A or B)	[22]
Operation and Maintenance (OM)	OM1. I believe that the operation of an EEHA is more complicated than my current heating solution OM2. I believe that an EEHA needs the user to perform maintenance work by himself OM3. I believe that the maintenance of an EEHA requires too much work	[16]
Co-benefits (CB)	CB1. Achieve a comfortable indoor temperature during the heating season more easily CB2. Have better indoor air quality CB3. Lower indoor noise level CB4. Lower external noise level CB5. Operate the EEHA more easily CB6. Be more independent to energy prices CB7. Have a more aesthetically pleasing EEHA CB8. Have a more useful living area CB9. Value the dwelling in the real-estate market CB10. Have a reduced environmental impact	[25,29,30]
Green Self-Identity (GSI)	GSI1. I consider myself worried with environmental problems. GSI2. I consider myself a "green consumer" GSI3. I worry about the effects of heating appliances on the environment and climate. GSI4. I worry about atmospheric pollution caused by the use of heating appliances.	[11,38]
Attitude on heating equipment use (AT)	AT1. I usually track my energy consumption based on my billing (dropped) AT2. I am willing to change my heating appliance(s) AT3. I am planning to buy an EEHA	[39]
Behavior intention to change to an EEHA (BI)	BI1. I intend to change to EEHA in the future BI2. I will try to change to EEHA in my future BI3. I am ready to change to EEHA	[40]

Table 2. Measurement Items

4.2. DATA

We created a survey in English that was analyzed by both a group of academics and energy and heating sector experts. Since the survey had as its focus the Spanish population, we translated it to Spanish and then again to English to guarantee that the survey had the same meaning for the two languages [41]. The survey was distributed to the general Spanish population (households) in an online format and was open for about three months. This questionnaire was shared with the help of some Spanish organizations specialized in energy consultancy, i.e., R2M, OCU.

Was collected a sample of 1136 responses. Figure 2, 3 and 4 characterize the sample in terms of "Number of children in the household", "Age" and "Gender".

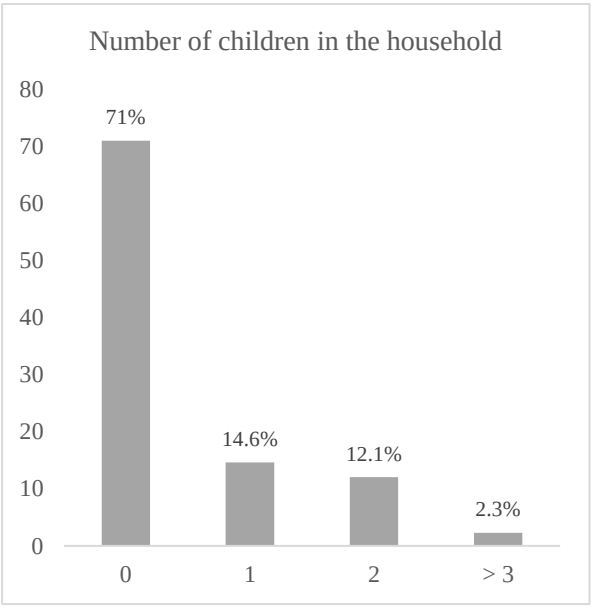

Figure 4. Distribution of "Number of children in the household" variable

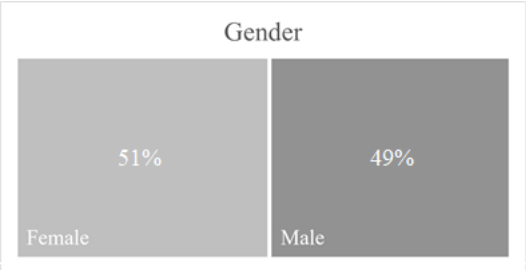

Figure 2. Distribution of "Gender" variable

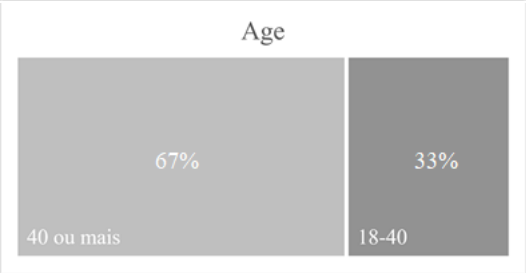

Figure 3. Distribution of "Age" variable

We applied the chi-square for the difference of probabilities test to confirm our sample against the Spanish population, which allows us to conclude that for gender and age, there is no statistically significant difference between our sample and Spanish population. The results of which are shown in Table 3. Thus, our sample proves to be quite realistic. The common method bias was also examined in two ways. First, we used Harman's one-factor test [42] and concluded that the first factor explains 25.8% of variance. This result means that none of the factors individually explain the majority of the variance. Second, we used the marker variable method [43] and obtained a value of 0.051 (5.1%) as the maximum shared variance with other variables. This value is considered low [44]. In that way, no significant common method bias was found.

		Sample	Spain	Test statistic	P-value
Gender				0.05	0.82
	Male	49%	49%		
	Female	51%	51%		
Age				2.47	0.12
	[18,40]	33%	33%		
	> 40	67%	67%		

Table 3. Sample (n=1136)

Note: data from Spain collected from Eurostat (data from 2018 and 2019)

5. DATA ANALYSIS

For this work was used the partial least squares (PLS) technique. This method is used when the constructs are modeled with formative constructs, the research model had never been tested before in the literature or when the model is considered quite complex [45]. We use variables that cannot be directly measured and therefore, we use measurement items to represent them. As such, the PLS SEM allow us to test our hypotheses with that measurement items, evaluating the direct and indirect relationships between the factors and our target. This method is considered that goes beyond of the usual multiple regressions [46]. Based on that information, this method was considered the best one since it fits the data that we have and meets the purpose of this work. SmartPLS 3.0 [47] was used to run the model, and analyze the model results.

5.1. MEASUREMENT MODEL

A measurement model was created to verify the internal consistency, convergent reliability, and discriminatory validity for the reflective constructs. In Table 4, the composite reliability (CR) results are higher than 0.7 for all constructs, which proves that all constructs are internally consistent [48,49]. Regarding the average variance extracted (AVE) measure, it was also verified that all constructs have AVE values higher than 0.5 (please see Table 4), which means that the convergent validity was demonstrated [48,50]. On analyzing the loadings, it is possible to conclude that all of them are higher than 0.7 (please see Table 5) [48,49]. Consequently, the indicator reliability was achieved. There are three methods to analyze the discriminant validity. The first is the Fornell-Larcker criterion [50]. To support this first criterion, the AVE square root of each construct should be higher than the correlation between the constructs, which happens in this work (please see Table 4). The second criterion is that the loadings should be higher than the cross-loadings [48], which we can observe that happens in Table 5. The third one refers to the heterotrait-monotrait ratio (HTMT) methodology. In this case, all the HTMT values should be lower than 0.9. Through the analysis of Table 6, it is possible to conclude that all constructs have a value lower than the threshold, except for behavior intention that presents a value of 0.913. For that situation, we applied the HTMT inference [51], and a confidence interval for that construct was created (with 10% of significance, the confidence interval is [0.884; 0.94]. Since the confidence interval does not include the value 1, we can affirm that all constructs have discriminant validity.

Constructs	Mean	SD	CR	AT	BI	S	L	OM	GSI
Attitudes (AT)	3.670	1.703	0.894	**0.899**					
Behavior intention (BI)	4.295	1.699	0.914	0.740	**0.883**				
Savings (S)	6.208	1.145	0.915	0.239	0.266	**0.885**			
Label (L)	6.393	0.968	0.925	0.214	0.266	0.436	**0.897**		
Operation and maintenance (OM)	3.441	1.441	0.933	-0.131	-0.186	-0.007	-0.081	**0.907**	
Green self-identity (GSI)	5.439	0.823	0.923	0.272	0.320	0.300	0.482	-0.021	**0.866**

Table 4. Descriptive statistics, correlations, composite reliability (CR), and average variance extracted (AVE)

Note: Values in diagonal (bolt) are the AVE square root; standard deviation (SD)

Constructs	Item	AT	BI	S	L	OM	GSI
Attitudes (AT)	AT2	**0.898**	0.643	0.233	0.197	-0.121	0.261
	AT3	**0.901**	0.688	0.197	0.188	-0.115	0.229
Behavior intention (BI)	BI1	0.664	**0.923**	0.237	0.245	-0.148	0.298
	BI2	0.610	**0.889**	0.290	0.281	-0.180	0.317
	BI3	0.682	**0.835**	0.181	0.180	-0.166	0.234
Savings (S)	S1	0.147	0.166	**0.744**	0.334	0.043	0.200
	S2	0.245	0.277	**0.950**	0.409	-0.021	0.294
	S3	0.227	0.246	**0.945**	0.411	-0.023	0.288
Label (L)	L1	0.187	0.230	0.412	**0.902**	-0.057	0.437
	L2	0.204	0.234	0.378	**0.919**	-0.069	0.447
	L3	0.185	0.250	0.384	**0.871**	-0.092	0.412
Operation and maintenance (OM)	OM1	-0.133	-0.182	-0.031	-0.077	**0.894**	-0.002
	OM2	-0.119	-0.161	0.005	-0.104	**0.908**	-0.047
	OM3	-0.103	-0.162	0.010	-0.038	**0.921**	-0.012
Green self-identity (GSI)	GSI1	0.190	0.239	0.292	0.438	-0.027	**0.837**
	GSI2	0.230	0.288	0.198	0.311	0.011	**0.791**
	GSI3	0.251	0.289	0.292	0.485	-0.027	**0.927**
	GSI4	0.264	0.286	0.262	0.436	-0.032	**0.903**

Table 5. Loadings and cross-loadings

Construct	AT	BI	S	L	OM	GSI
Attitudes (AT)						
Behavior intention (BI)	**0.913**					
Savings (S)	0.288	0.304				
Label (L)	0.261	0.307	0.501			
Operation and maintenance (OM)	0.158	0.212	0.037	0.091		
Green self-identity (GSI)	0.328	0.366	0.340	0.546	0.033	

Table 6. Heterotrait-Monotrait Ration (HTMT)

In order to assess the validity of the formative constructs, a measurement model was created to assess multicollinearity using the variance inflation factor (VIF). The VIF value of each indicator should be lower than 5 to guarantee that a problem of collinearity does not exist [48]. In this work, Table 7 shows that the VIF values are lower than 5 for all indicators. In terms of significance, the ten items are statistically significant ($p < 0.01$). Thus, we can conclude that the formative constructs are reliable.

Items	Mean	SD	Weights	Loadings	VIF
CB6	238.354	221.210	0.142***	0.826***	2.782
CB7	222.959	218.790	0.122***	0.863***	3.530
CB8	219.645	219.925	0.121***	0.836***	4.196
CB9	217.615	226.025	0.101***	0.792***	3.456
CB10	203.060	210.591	0.128***	0.859***	3.238
CB11	269.223	244.718	0.136***	0.835***	3.039
CB12	202.665	211.125	0.124***	0.762***	2.325
CB13	246.218	234.700	0.099***	0.763***	2.457
CB14	260.304	240.198	0.098***	0.758***	2.288
CB15	263.155	237.229	0.157***	0.813***	2.683

Table 7. Formative measurement model evaluation

Note: ***p<0.01; **p<0.05; *p<0.1

5.2. STRUCTURAL MODEL

Before assessing the structural model, we used the variance inflation factor (VIF) to test the multicollinearity of all constructs. The VIF value ranges from 1.03 and 2.76. The values are below 5 [48], which indicates the inexistence of the multicollinearity of all constructs. The structural model presented in Figure 5 contains the variation explained and the path coefficients. The bootstrapping method was used with 5000 resamples to obtain the significance level of the constructs in the hypothesized model.

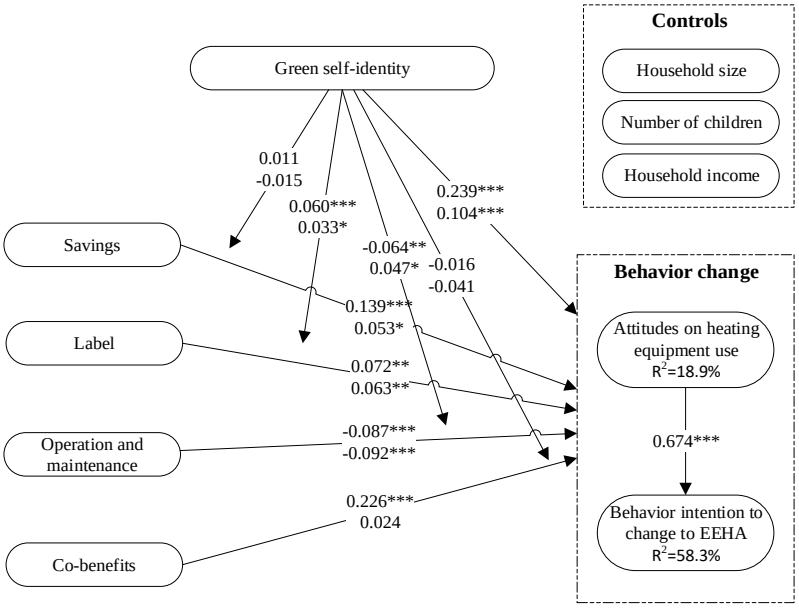

Figure 5. Structural model (variance-based technique) for behavior change to an EEHA

Note: ***p<0.01; **p<0.05; *p<0.1

Our model explains 18.9% of the variation on attitude on heating equipment use and 58.3% on behavior intention to change to an EEHA (this last one, is the value that has more relevance in the work). The savings construct is statistically significant for both behavior change (β̂a=0.139, p < 0.01; β̂b=0.053, p < 0.10). Thus, H1a and H1b are supported. The label is also statistically significant for both behavior change (β̂a=0.072, p < 0.05; β̂b=0.063, p < 0.05). Thus, H2a and H2b are also supported. The operation and maintenance construct is statistically significant for both behavior change (β̂a=-0.087, p < 0.01; β̂b=-0.092, p < 0.01). Therefore, H3a and H3b are also confirmed. The co-benefits construct is statistically significant for attitude on heating equipment use, but not for the behavior intention to change to an EEHA (β̂a=0.226, p < 0.01; β̂b=0.024, p > 0.10). Thus, H4a is supported, but H4b is not. The green self-identity construct is statistically significant for both behavior change (β̂a=0.239, p < 0.01; β̂b=0.104, p < 0.01). Thus, H5a and H5b are confirmed. The attitude on heating equipment use is statistically significant for the behavior intention to change to an EEHA (β̂=0.674; p < 0.01). Thus, H6 is also confirmed.

The moderating effect of the green self-identity in savings (β̂a=0.011, p > 0.10; β̂b=-0.015, p > 0.10) and co-benefits (β̂a=-0.016, p > 0.10; β̂b=-0.041, p > 0.10) is not confirmed, since it is not statistically significant. Therefore, H5.1a, H5.1b, H5.4a, and H5.4b are not confirmed. For the label (β̂a=0.060, p < 0.01; β̂b=0.033, p < 0.10) and operation and maintenance constructs (β̂a=-0.064, p < 0.05; β̂b=0.047,

$p < 0.10$), the moderating effect is statistically significant. Thus, H5.2a, H5.2b, H5.3a, and H5.3b are supported. Based on this analysis, it is concluded that the green self-identity factor not only explains the attitude on heating equipment use and behavior intention to change to an EEHA, but also moderates the relationship of label and operation and maintenance constructs. We can conclude that out of the 19 hypotheses in our research model, 14 hypotheses are supported.

Regarding the control variables, they are not statistically significant (p-value >0.1) in these model since they do not predict the change behavior regarding an EEHA. As such, it suggests that factors as the number of elements that constitute the household, the average household income, and the number of children in the household do not have impact and are not related with the behavior intention to change heating appliances by more efficient ones.

6. DISCUSSION

Overall, this work concludes that each of the model factors i.e., savings, label, operation and maintenance, co-benefits, and green self-identity, influence attitude on heating equipment use. In the case of the behavior intention to change to an EEHA, all factors have an influence, except for co-benefits. All significant factors positively influence the behavior change, excepting the operation and maintenance factor. It was also found that green self-identity moderates the relation between the label factor and behavior change and the operation and maintenance factor and behavior change. With our research model, it is possible to extend the existent literature review regarding heating appliances. It was taken a new perspective of the topic integrating five factors to explain the behavior change to an EEHA and understanding the role of environmental awareness. Globally, our model explains 18.9% of the variation on attitude on heating equipment use and 58.3% on behavior intention to change to an EEHA.

The results obtained directly confirm that the amount of energy and money that individuals can save when changing to an EEHA (savings) have a positive influence in the behavior change to an EEHA. This conclusion it is also in consonance with other studies that found that energy savings are an important factor when adopting some innovative residential heating system [28]. Regarding the presence of the energy label in the equipment, it is concluded that this factor positively influences the behavior change to an EEHA, which is consistent with other studies that conclude that energy efficiency label information has a positive impact in the behavior intention to purchase household appliances and energy-efficient appliances [22,23]. The work that the operation and maintenance of the equipment requires (operation and maintenance) negatively influences the behavior change to an EEHA, which makes sense since usually, individuals prefer to settle with the comfort of their current situation. To confirm that, Steg [32] concluded that consumers are less likely to save energy and change their behavior towards energy use if that involves high effort. Regarding the level of environmental concern that each individual has, it positively influences the behavior change to an EEHA. This finding makes sense since the change to an EEHA allows people to help the environment. This finding supports other studies, concluding that people with environmentally friendly behavior are more likely to have the intention to purchase energy-efficient appliances, namely efficient heating systems [10,24,26]. The benefits in terms of comfort, aesthetics, and safety that the change to an EEHA can bring (co-benefits) revealed to be only important for the attitude on heating equipment use. This aspect might be explained by the fact that people are usually more interested in other factors (like savings) than additional benefits when performing some renovation to their home like changing their heating system [25]. Also, due to that fact, they can consider that the co-benefits improve their willingness to change to an EEHA, but are not sufficient enough to influence the behavior intention to change directly. However, the total effect (i.e., the direct effect on behavior intention plus the indirect effect through attitude) of co-benefits to explain the behavior intention to change to an EEHA is statistically significant. Relative to attitude, as expected, this factor positively influences the behavior intention to change to an EEHA, as occurred in similar studies [23].

Regarding the moderating effects, it was possible to conclude that green self-identity influences the relationship between the label and both behavior change, i.e., attitude on heating equipment use and behavior intention to change to an EEHA, and also between the operation and maintenance and both behavior change. In Figure 6, for attitude on heating equipment use, it is concluded that when green self-identity is high, the operation and maintenance work is considered an even more critical barrier (negative factor) to explain the attitude. When the value of green self-identity is low, operation and maintenance is not such an important barrier to attitude on heating equipment use. This means that, for the attitude, the green self-identity of an individual will not positively contribute for the attitude, since the operation and maintenance factor is perceived as an even important barrier. However, for behavior intention to change to an EEHA (the most important behavior, that represents the change), the conclusions are different and more relevant. However, in Figure 7, for behavior intention to change to an EEHA, we can see that with a high value of green self-identity, the operation, and maintenance effect is not such a relevant barrier to explain the behavior intention to change to an EEHA. In contrast, when the value of green self-identity is low, the operation and maintenance work is considered a substantial barrier to explain the behavior intention to change to an EEHA. Thus, when the environmental awareness and concern of an individual is high, the operation and maintenance factor become less relevant, decreasing the importance of this barrier in the behavior intention to change to an EEHA, which means promoting more that change. Overall, this outcome reveals that green self-identity does not only have a direct effect on behavior intention but also mitigates the operation and maintenance barrier for the behavior intention to change to an EEHA.

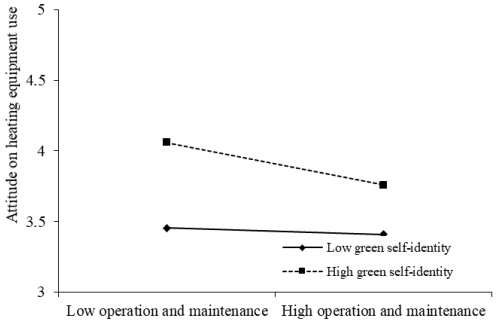

Figure 6. Structural model (variance-based technique) for attitude on heating equipment use

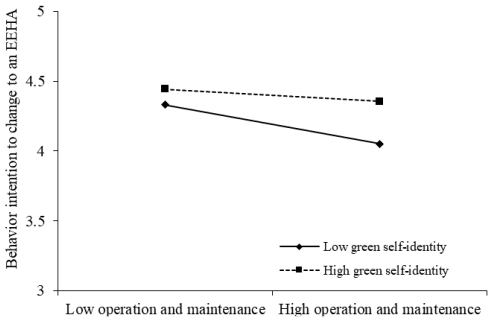

Figure 7. Structural model (variance-based technique) for behavior intention to change to an EEHA

In Figures 8 and 9, we can see that for attitude on heating equipment use and behavior intention to change to an EEHA, the conclusions are very similar. When a high green self-identity exists, the importance of the label is even more important in explaining both behaviors. This facet means that the energy label has a positive and stronger impact to explain both attitude and behavior intention when individuals have high environmental awareness compared to individuals that have low environmental awareness. Thus, when the environmental awareness and concern of an individual is high, the positive importance of having a label in the appliance become much more relevant, increasing even more the intention to change to an EEHA. These findings are consistent with other studies that conclude that the higher the environmental awareness, the greater the effect of the factors that influence behavior intention [33,34].

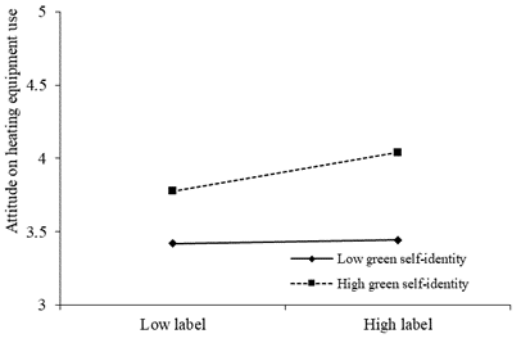

Figure 8. Structural model (variance-based technique) for attitude on heating equipment use

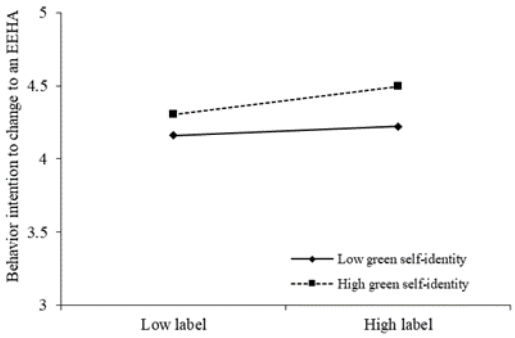

Figure 9. Structural model (variance-based technique) for behavior intention to change to an EEHA

However, our results also found the non-significant moderation effect of green self-identity on the relationship between savings and behavior change to an EEHA, and on the relationship between the co-benefits and behavior change to an EEHA. This aspect reveals that savings and co-benefits do not have different impacts for high or low levels of green self-identity, which means that both variables are important just by themselves, and their importance to explain both behaviors does not depend on the environmental awareness.

6.1. PRACTICAL IMPLICATIONS

In the context of help environment and change attitudes to a more sustainable ones, there is a concern with the energy consumed by buildings and households, as it represents a high value compared to other sources of consumption (actually, all buildings in Europe will soon be required to fulfil Nearly Zero-Energy Building (NZEB) standards [52]). The heating sector, therefore, takes a central role here, being important in the success of the ambitious global climate goals [53]. Thus, given the work carried out, there are several important implications for policymakers, energy agencies, and those responsible for the promotion and selling of EEHAs.

First, our studies indicate that in order to change to an EEHA, an important factor will be to inform individuals of the real work that the equipment requires. With the perception of the work required with the appliance being an important factor that leads to not changing, it is necessary to ensure that people have accurate information about what manifestly needs to be done to install and operate the new equipment. Thus, this type of information must be available at the sellers. Second, the energy label must be present on all equipment, as this is one of the aspects to which individuals pay more attention. As such, the energy label must be appealing and highlight the equipment energy classification. This suggestion may be more targeted at energy agencies. Third, information about both energy and monetary savings that can be obtained when changing to an EEHA should also be promoted to the public. Thus, specific case studies should be carried out that unequivocally prove this situation, in order to encourage the change. Since the monetary part is something of relevant impact, perhaps the allocation of initial subsidies can also encourage the change to an EEHA. Finally, it is essential to appeal to the environmental identity of each individual. Increase the environmental awareness e.g. via education system, will inculcate the culture of energy saving among individuals [54]. Here,

governments and policymakers can act by establishing some restrictive measures in relation to energy use and long-term energy reduction goals for buildings, as they have already been doing in some countries.

6.2. LIMITATIONS AND FUTURE RESEARCH

Despite the contribution of this work, since it was only carried out in Spain, it would be interesting apply this model to data from other countries. Due to the relevance of this topic for different areas, namely environmental sector and even for achieving the European objectives defined in the Horizon 2020 initiative, we believe that would be worthwhile and a good contribution for other countries to apply the suggested model, developing a similar analysis. A limitation is the fact that this work was only carried out for household heating appliances. It would be relevant to do the same work but with other large appliances and even in other buildings such as companies. Equally important would be the use of moderators in further studies in this energy sector (not just the environmental concern of each individual), since it is not profoundly studied in the existing literature.

7. CONCLUSION

The “energy efficiency” is one of the most important principles for European Union, being the most cost effective way to meet the long-term vision to lead the transition to a climate neutral economy by 2050 [55]. In that way, the environmental protection and sustainable utilization of the resources is an important issue, being extremely relevant to adopt sustainable practices, namely in the residential sector [56]. Thus, this work focused on the direct and moderating effects of drivers to change to an EEHA. More specifically, this work found the main factors that influence behavior change to an EEHA, i.e., savings, label, operation and maintenance, co-benefits, and green self-identity, through a literature review. We conclude that savings, label, operation and maintenance, and green self-identity factors are significant influencers of the behavior intention to change to an EEHA, and all factors are important for attitude on heating equipment use. We found that all factors positively impact the behavior intention to change to and EEHA with positive path coefficients and p-values < 0.1, except the operation and maintenance that has a negative impact, with a negative path coefficient ($\hat{\beta}$b=-0.092, p < 0.01). As such, our model explains 58.3% of the behavior intention to change to an EEHA. We also concluded that green self-identity moderates the relationship between labeling and both attitude on heating equipment use and behavior intention to change to an EEHA; and between the operation and maintenance and both behaviors. As such, out of 19 hypotheses in our research model, 14 hypothesis were supported. Overall, it can be concluded that possible energy and money savings obtained through the change to an EEHA and the presence of the positive energy label classification on the appliance can positively influence individuals to make the change to an EEHA. Since the change to an EEHA is also a pro-environmental behavior, people who are concerned with the environment are more prompt to change to an EEHA. The operation and maintenance of the appliance can be a cons to the behavior change. However, if the individual is concerned with the environment, that cons become less important, mitigating that barrier to the change. Also, the label becomes a more impacting factor when an individual is preoccupied with environmental aspects.

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