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Conversion of Residential Heating Systems from Fossil Fuels to Biofuels: A Cross-Cultural Analysis †

Diana A. Londoño-Pulgarín *, **Francisco Muñoz-Leiva** and **Esmeralda Crespo-Almendros**

Department Marketing and Market Research, Faculty of Business and Economics, University of Granada, Campus La Cartuja s/n, 18071 Granada, Spain; franml@ugr.es (F.M.-L.); ecrespo@ugr.es (E.C.-A.)

* Correspondence: dianalondono16@gmail.com

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Abstract: This paper aims to analyse: (a) how the attitude towards renewable energy-based heating systems, pro-environmental behaviour and the perceived attributes of technology influence intention to convert residential heating systems from fossil fuels to biofuels, and (b) the moderating role of culture based on Hofstede's individualism dimension. A total of 425 responses were collected from a panel of internet users from representative countries in three continents (the United States, the United Kingdom and South Africa); the data analysis was carried out using structural equation models in a multigroup analysis. The results showed that attitude towards renewable energy-based heating systems is influenced by environmental variables in the United States and the United Kingdom, and by the perceived attributes of clean residential heating systems in the United States and South Africa. Attitude, in turn, impacts on the intention to convert from fossil fuels to biofuels. In addition, individualism has a moderating effect between these variables and there are intercultural differences in the degree of importance attributed to them. The study concludes the use of these energy systems as drivers of environmentally-sustainable development.

Keywords: environmentally-sustainable development; renewable energy sources; fossil fuels; residential heating systems; intention to convert to bio-fuels; cross-cultural analysis

1. Introduction

Due to the increase in global energy demand, the primary sources used by humankind to satisfy its energy needs are varying [1]. This variation is due, above all, to the attempts to address the problems created by this increase in energy consumption, such as environmental deterioration, depletion of non-renewable resources and global warming. The main cause of climate change is the carbon dioxide (CO_2) released into the atmosphere by the use of petroleum products, natural gas and coal, that is, greenhouse gas emissions [2]. Although these fossil fuels help meet global energy needs, they have a disastrous effect on the atmosphere, the economy, and society [3].

Concerns about the environmental crisis have led governments to introduce pro-environmental policies and actions to minimize these negative effects [4]. Among the actions, sustainable development (SD) approaches have moved to the national policy level. Sustainable development aims to maintain a balance between current human well-being and the conservation of natural resources and ecosystems; that is, it seeks to meet current energy needs without sacrificing the capacity of future generations [5] (p. 314).

According to the United Nations Commission on Sustainable Development and the Organisation for Economic Cooperation and Development (OECD), SD has four pillars: (1) social, (2) economic,

(3) environmental and (4) institutional [6,7]. Kühtz argued that the third involves environmental capital and the sum of "bio-geological processes" [8] (p. 156); these include clean energy components.

This vision has encouraged the development of plans to incentivise businesses and individuals to carry out behaviours with sustainable purposes [4,9]. To accomplish this, Kühtz proposed four paths: (1) the promotion of long-lasting behavioural changes, (2) the promotion of an ecological vision in line with global objectives, (3) the support of private initiatives focused on sustainability and (4) the strengthening of the sense of global solidarity [8] (p. 155).

Similarly, as governments seek to promote a change from environmentally-harmful energy systems to environmentally-friendly systems, so the next step should be the technological conversion to sustainable systems for domestic and industrial use. Biomass-fed heating systems could provide this as a clean technology [10]. Biofuels could be used to generate mechanical, electrical and thermal energy, for use in cities, industries and homes, in a closed carbon cycle that does not emit additional CO_2 [11,12]. The diffusion and adoption of biofuels as drivers of environmental SD would help meet this challenge.

Thus, the efficient development of bioenergy for residential use is included in the international sustainability agenda and has attracted interest in the social research arena [13–17]. Its application in heating devices will depend, in part, on householders' conversion intentions and the ability to assess potential demand in the bio-heating market [18].

Consequently, there is a need to know what variables affect and determine the acceptance of these systems at the residential level in different countries, taking into account cultural differences and geographical perspectives [16,19,20]. To address this, a cross-cultural approach is adopted to analyse the effect of the cultural characteristics of consumers from different countries on the distinct behavioural factors behind the use of household energy systems.

Additionally, it should be taken into account that in this type of research, in terms of individuals' adoption, there is a methodological heterogeneity and therefore, three perspectives stand out: (1) from the line of consumer behaviour and marketing, it seeks to understand what internal or external variables influence consumption patterns and the intention to purchase products and services or not to do it, in a specific purchasing scenario [21].

(2) With the process of dynamic adoption of innovations and technologies from the perspective of the user adopter based on the technological management of innovation approach and its influence on other consumers (networks). It seeks to reconcile the dynamic evolution of the actions, interactions and decision strategies of autonomous individuals (agents), framed in their nearby social networks based on their current level of satisfaction and the uncertainty associated with a product. In the same way, it seeks to understand what determines the state of adoption in time and space during the life cycle of technology, learning and the different profiles of adopters that exist in a process of diffusion within a social system [14,22,23].

(3) From the neuromarketing perspective, it seeks to know the level of objective response that certain marketing stimuli generate, this to achieve predictions about consumer behaviour and the mental processes presented, that is, this allows to know the psychophysiological reactions of the consumer without having to resort to their conscious experience [24–26].

Based on the above, the present study aims to contribute to previous research into the sustainable behaviour of households in different countries, from consumer behaviour perspective based on an empirical analysis that supports a decision-making model for converting to bioenergy-based heating systems; an analysis is included of the effects of certain user perceptions, and how culture moderates these relationships. The aim is to explain what drives the adoption of these technologies, to support the formation of global environmental change strategies to fulfil sustainable development goals (SDGs); in this way, the various social actors, while taking into account the cultural differences of international markets, might make better decisions regarding the diffusion and commercialisation of environmentally-friendly thermal alternatives.

This paper is organised as follows: the next section presents a description of the renewable sector in number per each country; the third section exposes a review of the literature on the study variables and justifications for a series of proposed research hypotheses; the fourth section describes the main methodological issues; the fifth includes the data analysis, the main results and discusses the main conclusions, the last section addresses the limitations and future research lines.

2. The Renewable Sector in Numbers. The Case of the United States, the United Kingdom and the Republic of South Africa

2.1. United States of America

With the implementation of the National Environmental Policy Act No. 91, 1 January 1970, the United States (US) recognizes the impact of human activity on the interrelationships of all components of the environment, and for this reason, starting that year, it has implemented a series of policies that seek to reduce polluting emissions. With this, it intends to assume control over the previous ones through research and investment in prevention, reduction and control projects [27].

To materialize the above, the US Environmental Protection Agency (EPA) was created; this entity is responsible for enacting the Affordable Clean Energy (ACE) standard, issued on 19 June 2019 [28]. This established a norm which empowers the states of this country to achieve energy efficiency and a greater reduction in harmful emissions for the environment while providing accessible and reliable energy for all citizens; this implies a reduction of energy when providing products and services.

It should be noted that the US benefits from and produces several different types and sources of power. In 2017, according to the EIA, the total production of alternative sources of energy such as nuclear, renewable and others, was 19.71181552 quadrillion BTU (British thermal unit-quad-BTU), which represents approximately 22% of the participation of these energies in the total production of clean energy technologies (CET), which was 4.3% higher than in 2016 (18.849265074 quad BTU) [29]. Concerning the final energy consumption, which in 2017 was 5,696,688 Tera Jules (TJ), in the first place, there is the consumption of solid biofuels with 32%, followed by the expenditure of liquid biofuels with 29% and the hydroelectric energy with 17%, representing a reduction of 1% for all, compared to the immediately previous year [30]. It should also be mentioned that, in 2019, the total consumption of renewable energy was 11.4 quad BTU, which represents 11% of the primary power consumption in the US, being biomass the most widely implemented with a 43%, wind energy with 24% and in third place hydroelectric power with 22% [31].

In the US, the use of heating represents the highest energy demand in the residential sector. Natural gas is the main source of heating, it supplies around two-thirds of the energy demand for room and water heating. The remaining third is supplied by oil and electricity, plus a small part from biofuels [32]. Since 2006, residential oil consumption has decreased by 27%, while the use of renewable energies (electricity output/Gigawatts hours-GWh) has shown a constant increase (2015: 568,439 GWh; 2016: 637,076 GWh; 2017: 718,175 GWh; 2018: 743,179 GWh; 2019: 757,785 GWh) [33].

2.2. United Kingdom

The United Kingdom (UK) is located between the mid and high latitudes of the northern hemisphere, and west of the Eurasian continent. It corresponds to a cold and humid climate whose average temperatures in the coldest months are −15 °C to 3 °C.

It is a world leader in decarbonising both, in terms of actual emission reductions and, the established goals in the five-year estimations. The country has supported the coal-to-gas switching which, combined with record investment in wind, marine and solar PV, is transforming the UK energy sector. By 2030, wind and solar power are expected to exceed 50% of the variable renewables share. Coal and nuclear power capacity will be replaced, and the contribution of natural gas is likely to increase to meet its peak demand [34].

It should be noted that within the UK's total energy production for 2017 (5.2656544542594 quad BTU), approximately 1.4% came from coal (0.077603633135087 quad BTU), 30% from natural gas (1.6034549201243 quad BTU), 39% from oil (2.054851583 quad BTU) and 29% from renewable (1.529744318 quad BTU). Regarding these data, in 2016 there was a reduction in coal production, this being 0.10661396719425 quad BTU; natural gas production for this same year increased since it presented a figure of 1.5864355111082 quad BTU. Like coal, oil decreased, as this figure for 2016 was 2.095205794553 quad BTU. Finally, the production of renewables for 2017 increased, since in 2016 a total of 1.422137325022 quad BTU was presented [29].

In addition, it is important to highlight the role of renewable energy for the UK; according to EIA, its sources have been increasing to a great extent, showing favourable results. In 2016, its generation was 83,728 GWh, 99,577 GWh in 2017, 110,812 GWh in 2018, and 119,335 GWh in 2019, this being the highest [33].

During 2016, 85% of UK homes had gas central heating, only 6% used renewable energies and less than 2% implemented district heating. Due to the policies implemented by the UK that same year, there has been an increase in the energy efficiency of the existing gas and renewable energy heaters and for this reason, residential renewable heat installations technologies were promoted in 65,000 homes [34].

Since conventional fuels are present in around 170,000 homes, in 2018, the UK presented a plan to decarbonise the heating sector, prohibiting the installation of oil and coal heating in new houses starting in the year 2020 [34].

2.3. South Africa

Currently, the growing power demand comes from middle and high-income homes. This is why Africa is presenting an energy transition plan, taking into account that its main source comes from coal; thus, it seeks to generate new opportunities through the implementation of different resources [35]. According to the Ministry of Mineral Resources and Energy of the Republic of South Africa (SA), the total national electricity generation capacity was 5.9345678560078 quad BTU during 2017 [36]. Approximately 91.2% comes from thermal power plants, while 8.8% is generated from renewable energy sources [36].

From the aforementioned figures, according to the US Energy information administration (EIA), for the year 2017, the total production of alternative energy sources such as nuclear and renewable was 0.239465112 quad BTU; energy generated from sources such as oil presented a figure of 0.00752338 quad BTU, natural gas reached the figure of 0.0336101577381 quad BTU, and finally the highest figure was coal production with 5.6539692062697 quad BTU, representing approximately 95% of total energy production for that year [29].

On the other hand, according to the International Energy Agency (IEA) report "Africa Energy Outlook 2019", the role of coal, peat and shale oil in the South African industry and the power generation from these sources is already declining (2016: 98,684 kilotonnes of energy equivalent—Ktoe (Kilotonne of Oil Equivalent); 2017: 98,653 ktoe; 2018: 98,284; ktoe; 2019: 91,271 ktoe), while renewables increase (2015: 8468 Ktoe; 2016: 8745 Ktoe; 2017: 8995 Ktoe; 2018: 9230 Ktoe) [33].

Regarding the latter, the consumption of renewable energies in SA homes represented 34% of the total value in 2018 (3197 Ktoe) [33]. Both, in urban and rural areas, electricity is the number one option for heating and cooking, especially in winter during June, July and August and with average temperatures of 6 °C; this is so since it is located in the southernmost part of the African continent and its latitude and longitude are −30.559482 and 22.937506, correspondingly. Notwithstanding the above, more than 4 million homes, mainly in rural areas, continue to use firewood [35].

Given the above and, that according to the IEA, conventional thermal energy sources will probably be dominant in the generation of electricity in the foreseeable future; within this country's 2030 National Development Plan, renewable infrastructure and energy development and natural gas are expected to be promoted, thus reducing SA's energy dependence on coal [35].

3. Review of the Literature and Hypotheses

3.1. Attitude towards Renewable Energy-Based Heating Systems and Intention to Convert to Biofuel-Based Systems

Attitude has been defined as politomic subjective manifestations experienced by an individual, before performing a particular behaviour, which is activated based on his/her beliefs or thoughts [37]. The intention has been defined as the feeling an individual has of being ready and having plans to perform (or not) a particular behaviour [38,39].

Attitude has been used in environmental-sustainability research [40–43]. Several studies have shown that attitude can influence the intention to carry out sustainability actions, and several clean technology studies have used the behavioural intention conceptual framework [15,16,44–54].

Van Rijnsoever and Farla argued that sustainable attitudes reflect the positive orientation of people towards environmental conservation [55] (p. 74), and that they are, in turn, antecedents of intention to participate in related actions, such as using renewable energy [48] (p. 320).

Consequently, attitude towards bio-energies could be a predictor of intention to help reduce environmental problems by converting to biofuel-based systems [49] (p. 274). Thus, the following research hypothesis is posited:

Hypothesis 1 (H1). *A positive attitude towards renewable energy-based heating systems (ATT) positively influences the intention to convert to biofuels in residential heating systems (INT).*

3.2. Influence of Pro-Environmental Behaviour on Attitude and Intention

Fujiki and Zheng defined pro-environmental behaviour (PB) as "any action that contributes to environmental preservation in daily life" [56] (p. 1). PB includes: (1) all behaviour that encourages improvement or preservation of the environment; (2) concern about environmental issues, and; (3) values inspired in the individual by respect for nature conservation [44,57–60].

The literature shows that consumer PB influences positive attitudes towards the environment [47] (p. 3170). Therefore, individuals with environmentally-sustainable values develop positive emotions, thoughts and intentions towards the use of clean technologies [17]. Thus, because favourable attitudes have already been formed, consumers become more prone, or predisposed, to convert to environmentally-friendly systems; this favourable attitude has great causality in the decision to adopt clean products [39,44,48,51,55,56].

However, there are two cases in which individuals give less importance to PB. The first is related to their financial and socioeconomic status because sustainable systems tend to be more expensive [61]. The second relates to the consumers' personal values, as the propensity to change technologies can be influenced by social status [62], by their level of knowledge about the benefits of the use of sustainable technologies (e.g. [63]; [55], and by risk aversion [64].

Based on these arguments, pro-environmental behaviour influences attitude and intention, and thus the following hypotheses are proposed:

Hypothesis 2 (H2). *PB positively influences ATT.*

Hypothesis 3 (H3). *PB positively influences INT.*

3.3. Influence of Technology Perceived Attributes on Attitude and Intention

The perceived attributes of clean residential heating systems (ATR) are perceptions that consumers have about the regulations, social norms and attributes of the systems. These factors can be economic or not and can be perceived by individuals as motivators or barriers to investment in specific technologies [65–67].

Consumers make purchasing decisions based on the perceptions they have about external factors. Thus, they analyse the incentives provided by both government institutions and businesses [49,67] and compare available heating systems based on the perceived attributes of the equipment [68] (p. 78) (See the list of attributes in Appendix B).

ATRs are important for technology adoption; it can be inferred that they improve or worsen attitude and, therefore, influence the intention to convert [65,69]. Similarly, the technological acceptance model (TAM; [70]) explains this approach; the TAM shows that motivation, represented by the attitude that a user has towards the use of a certain system, influences whether or not it will be adopted.

Based on these arguments, ATRs are expected to influence attitude formation and, in turn, influence, through ATT, intention to convert. Thus, the following hypotheses are proposed:

Hypothesis 4 (H4). *ATRs positively impact ATT formation.*

Hypothesis 5 (H5). *ATRs positively influence INT.*

3.4. Moderating Role of National Culture

Culture encompasses the material and immaterial factors that identify a group of people who share the cognitive, emotional and behavioural patterns of a social environment [71–76]. Culture is an important personal element [77,78] and influences the formation of expectations around consumption phenomena [79] (p. 58), such as the propensity to convert to new technologies [80]. To identify contrasting approaches and behaviours between different international cultures, cross-cultural comparative analyses have been carried out [81] (p. 57). At the national level, differences in cultural values have been categorized into various dimensions. These dimensions are based on country scores developed from specific variables, applying statistical data reduction methods (e.g., factor analysis) [78] (p. 13). Of the three main models used for cross-cultural analyses of consumer behaviour (Hofstede, Schwartz and GLOBE), the most used is that of Hofstede [82]. This model consists of 6 dimensions, individualism vs. collectivism, power distance, masculinity levels, uncertainty avoidance, long-term orientation and indulgence [83].

Although Hofstede's dimension scores were first presented in the 1970s, later studies have shown that this classification by country remains valid [75] and applies to modern cross-cultural studies [84,85]. In addition, several authors have verified the validity of the dimensions to show the behaviour of different cultural groups (De Mooij, 2001; cited in [79] p. 58). However, some authors have found errors in models due to the confusion of national and individual scores; multilevel comparisons between countries can only be made when analysing how variables affect people's perceptions, in general, at the national level [84,86–88].

Delving deeper into Hofstede's dimensions [83], individualism—IDV—has been predominant in cross-cultural studies [89] (p. 182), [86] (p. 650), including those related to sustainable technology adoption (e.g., [90–92]). Individualism relates to the extent to which the decisions people make about their lives are determined by themselves or their close circle [90]. Members of highly-individualistic societies are expected to consider their interests over those of the group [93]. On the other hand, when IDV is low, individuals are collectivist and are inclined towards cooperation, as reaching consensus and forming a mutual trust is their ultimate goal [89].

Regarding approaches to environmental sustainability, collectivist countries are culturally more prone to perceive sustainability as an important societal objective, but the adoption curve is retarded due to the level of consensus required [92], while highly-individualistic countries, which usually have greater ecological activism, will have greater social and institutional capacity to address environmental sustainability [90]. In addition, Tata and Prasad [92] noted that, although Husted [90] and Vachon [94] identified a positive relationship between individualistic values and environmental sustainability, Waldman et al. [95] found a negative relationship, and Park et al. [91] and Ringov and Zollo found no significant relationship [96] (p. 282). It is important to highlight that, in this sense, we did not find conclusive studies on biofuel heating issues. However, based on the results of previous studies (e.g., [97–99]), it is expected that, at the national level, consumers will have different predispositions towards adopting residential biofuel heating systems based on the country where they live.

Taking these points into account, the present study makes multilevel comparisons between the countries under study through a multigroup analysis [86] (p. 657) based on IDV, to explain attitude towards converting to thermal bioenergy, and raises the following research question (RQ):

RQ: *Does IDV has a moderating effect on some of the previously-hypothesized relationships?*

Based on the hypotheses, an integrative theoretical model is proposed (Figure 1). The model includes the relationships between the constructs advanced in the theories and revised models in the field of the adoption of environmentally-sustainable technologies. It includes also the moderating effect that the cultural dimension IDV exerts on these relationships, based on the national scores established by Hofstede [83] (dotted lines), for which a multigroup analysis was carried out.

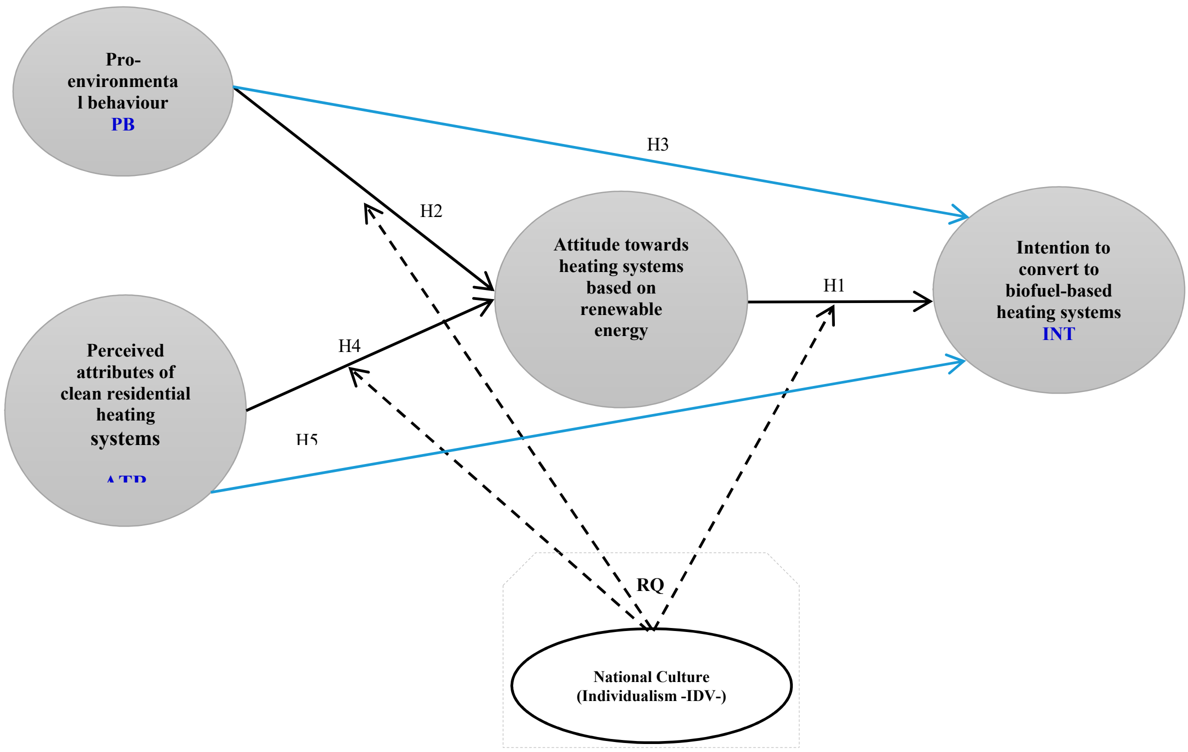

Figure 1. Proposed model. **Source:** Created by authors.

4. Methodology

4.1. Rationale for Country Selection

To carry out the present cross-cultural analysis, nation-states belonging to the Organization for Economic Cooperation and Development (OECD) were chosen. Countries that are located at least E23.5 degrees' north latitude and south of the Equator and that, therefore, have their climatic seasons clearly defined throughout the year (different from countries in the tropics). Indeed, the citizens of these nations could be prone to use residential CETs to heat or cool their homes, which allows the study to anticipate the conversion of fossil fuels to biofuels behaviours in residential heating systems. In the same way, the selected nations are characterized by emitting greenhouse gases (GHG) by producing and consuming renewable energy (solar, wind, biofuels and biomass) in their territory.

The aforementioned selection criteria were considered because when dealing with green energy behaviour, special reference is made to the rise of renewable energy sources and two main reasons are taken into account: the inevitable depletion of fossil fuels and global warming. Therefore, the production and consumption of energy from renewable sources must be evidenced in the increase, permanence or decrease of GHG emissions [2]. To be more specific, this study evaluated certain environmental energy variables of the countries, such as the measurement of CO_2 emissions, gross power consumption from renewable sources, the energy shares from renewable sources within the total balance of energy production, and the energy share from renewable sources within the consumption basket of energy sources.

Once the preselection was made, which was initially composed of 46 countries, an additional comparison was made according to cultural criteria, using two-stage clusters with hierarchical centroid grouping using SPSS software, since the particular interest of this research consists on performing a cross-cultural analysis and its moderating effect on the factors that influence sustainable behaviour. In this sense, according to Park et al., the concern and a society's green behaviour are due to the will and capacity to protect the environment of the groups, which are also influenced by intra-country sociocultural factors [91] (p. 105). National culture is expected to influence the way people use natural resources and environments by shaping their behavioural perceptions, attitudes, and intentions [91]. Therefore, in the present study, the cultural scores at the national level of the preselected countries were taken into account according to the approach proposed by Hofstede [83], this author proposes 5 dimensions in his studies. These are scored for each country between zero and one hundred: (1) Power Distance, (2) Uncertainty Avoidance, (3) Long-term Orientation and level of Masculinity and (5) Individualism vs. Collectivism. These dimensions also present differences, specifically in the environmental characteristics for nations according to the score the author assigned to each society.

At this point, based on cultural criteria and language, three English-speaking countries from different continents with different Hofstede dimension scores [73] were selected for the present study: the United States (US), the United Kingdom (UK) and South Africa (SA).

According to Hofstede [73], the American society is characterized by a low power distance index (PDI) (score: 40), which shows that it is a culture with little fear to the authority, where there is a belief that inequality between individuals related to power, status and wealth should be minimized [71]. The uncertainty avoidance (UAI) from the US is not an accentuated characteristic (46), they have a low level of fear for instability or changing norms. American society is individualistic (91), it tends to place a higher value on autonomy and individual freedom [73] and they care more about themselves (their personal achievements) and their family closer. The masculinity dimension (MAS), is at an intermediate level (62). As a last resort, it is a short-term culture (23), as immediate concerns are more important for these individuals.

British society, as well as North American society, is characterized by a small-PDI (35). In this culture is thought that inequalities between people should also be minimized. With regard to risk aversion, the British feel comfortable in situations of uncertainty as they have a weak-UAI index (35). This index is 10 points lower than the US, therefore they are more tolerant of the events that happen every day. On the other hand, it is a culture that tends to give greater importance to individualism and downplays the importance of belonging to groups with collective interests (89). This society is a long-term orientation culture (LTO) compared to the US and SA (51); of the three countries, UK is the one that presents a greater propensity to adapt to changing circumstances over time. The MAS dimension is an intermediate characteristic in British society (66); as in the US and SA.

Finally, South African society has the highest PDI and UAI of the three countries (49); it continues to be on a medium level. This culture adapts to unstructured or unknown situations and it has low respect or fear to the authority. Their LTO is low (34), therefore, instant gratification is important. This society is medium individualism (65).

4.2. Sample and Data Collection

The three countries mentioned above, with varied Hofstede [83] IDV dimension scores, were selected for the cross-cultural analysis (US, UK and SA). User panels in these countries undertook a structured online survey on august 2017 (https://webcim.qualtrics.com/jfe/form/SV_eVRrVr9tWsA0TB3), managed by Toluna (https://es.toluna.com). An effective sample size of 425 current and potential users of heating systems (based on different fuels, e.g., biofuels, traditional fuels, etc.) was obtained. The sample was distributed as follows: US (38.4%), UK (29.9%), SA (31.8%) (see sample characteristics in Table 1). The target population was owners (aged over 19) of single-family homes with independent heating systems. Gender and age quotas were established proportional to the national total of single-family households, without distinction between rural and urban areas.

Table 1. Sociodemographic characteristics of the respondents.

Variables	Categories	US%	UK%	SA%	Total%	*n*
Gender	Female	57.06	59.06	58.52	58.12	247
	Male	42.94	40.94	41.48	41.88	178
Age Range	20–30	20.86	15.75	20.00	19.06	81
	31–40	33.74	27.56	31.11	31.06	132
	41–50	12.88	23.62	24.44	19.76	84
	51–60	12.27	9.45	17.04	12.94	55
	61–65	6.75	4.72	5.19	5.65	24
	66–70	7.36	6.30	1.48	5.18	22
	>70	6.13	12.60	0.74	6.35	27
Civil Status	Single	9.20	16.54	22.22	15.53	66
	Couple without dependent children	19.63	39.37	17.78	24.94	106
	Couple with dependent children	52.15	31.50	43.70	43.29	184
	Separated without dependent children	4.91	4.72	4.44	4.71	20
	Separated with dependent children	7.36	5.51	5.19	6.12	26
	Widow(er) without dependent children	4.29	2.36		2.35	10
	Widow(er) with dependent children			1.48	0.47	2
	Other	2.45		5.19	2.59	11
Level of Education	High/Secondary school	19.63	36.22	20.00	24.71	105
	Lower University Degree	39.26	40.16	44.44	41.18	175
	Higher University Degree (Master, PhD)	39.26	22.83	29.63	31.29	133
	Other studies	1.84	0.79	5.93	2.82	12
Current Occupation	Student	2.45	2.36	0.74	1.88	8
	Housewife	4.29	4.72	0.74	3.29	14
	Retired	20.25	23.62	519	16.47	70
	Unemployed	2.45	3.15	2.96	2.82	12
	Business owner	7.36	7.87	11.85	8.94	38
	Employed	57.67	56.69	72.59	62.12	264
	Freelance professional	5.52	1.57	5.93	4.47	19

Source: Created by authors.

The sample size selection was obtained based on the parameters of the structural equation model (SEM- which is a multivariate statistical technique for testing and estimating causal relationships between variables or constructs from statistical data and qualitative assumptions about causality by the hypotheses [100]) establishing a lower bound [101]. To achieve this, the calculator software of Soper [102] was used, which yielded a minimum apriori sample size to detect the effect of 376 observations from the parameters of the SEM model supported in the present study; which is made up of 5 latent variables or constructs and 26 observed or measurable variables, with a reliability of 95% (0.05) and a desired statistical power level of 80% [103,104]. Likewise, the Hoelter´s critical N from the AMOS software was applied to test the adequacy of the sample size and whether it is sufficient or not from the data obtained [105]. The accepted threshold for Hoelter's Critical N is 200 for good fit and values below 75 are considered unacceptable (75 ≤ value < 200; acceptable ≥ 200) [100,106]. Based on these thresholds, a sample size of 425 is accepted for the study since the Hoelter´s index as a goodness o fit measure yielded a minimum sample size of 219 observations with a 95% of reliability.

4.3. Variable Measurement Scales

Politomic questions were posed to establish an intention to convert to biofuel heating systems. To measure the variable "attitude towards heating systems based on renewable energy" (ATT), a 5-point Likert-type scale was used, from 1 ("Strongly disagree") to 5 ("Strongly agree"); this scale was previously developed by Fishbein and Ajzen [107], and later adapted by Todd and Taylor [108] and Sopha and Klöckner [39] (Appendix A).

The "perceived attributes of the system" (ATR) were measured through a 5-point Likert-type scale, from 1 ("Not important") to 5 ("Very important"), adapted by Sopha et al. [65] and Lillemo et al. [66] (Appendix B). While these authors made comparisons between systems based on different technologies (e.g., Lillermo et al. [66] focus on four types of heating equipment: woodstoves, pellet stoves, electric heaters and air-to-air heat pumps; Sopha et al. [65] focus on electric heating, heat pump and wood pellet), in the present study we posed the questions in a more general way, that is, this study does not focus on any specific energy technology.

Pro-environmental behaviour, or concern for the environment, was measured using the "Revised New Environmental Paradigm Scale" (NEP) from 1 ("Strongly disagree") to 5 ("Strongly agree"), adapted by van Rijnsoever and Farla [55]. This scale was originally developed by Dunlap and Van Liere [109] to evaluate 15 items focused on pro-environmental orientation; these examined humankind's interference with the vulnerable balance of nature and its ability to alter the environment [110]. Some items had inverse scores, so greater agreement indicated more pro-environmental behaviours (Appendix C). According to Fielding et al. [48], the results of the study by Dunlap et al. indicated that the scale was internally consistent, one-dimensional and predicted environmental behaviour [111] (p. 321).

4.4. Data Analysis Techniques Used

To represent the sociodemographic characteristics of the respondents and their behavioural intentions, a descriptive, or frequency, analysis was carried out, using the IBM SPSS Statistics 22 program. In addition, prior to estimating the proposed model, an exploratory factor analysis (EFA) was carried out to define the possible subcategories of each construct by analysing the Kaiser-Meyer-Olkin (KMO) indicators and through Bartlett's test of sphericity (BTS).

A confirmatory factor analysis (CFA) was then applied to the ATT, ATR and PB constructs to detect possible patterns. Thereafter, tests were applied to verify the reliability and to confirm the internal consistency of the items, based on goodness of fit indicators (AMOS v24) taken from the estimation methods applied (following Ullman [112]; Uriel and Aldás [113]; Ximénez and García [114]; Brown [115]; Valdivieso [116]). In particular, given the non-normality of the data, the unweighted least squares (ULS) estimates method was used. However, to obtain some complementary indicators the maximum likelihood (ML) method was applied, as this allowed estimation of the parameters, the T-Student values and their significance values (p); Promax rotation was used.

The estimation of the proposed model allowed us to carry out tests of reliability and of convergent and discriminant validity. Similarly, a two-procedure factorial invariance test was carried out. First, a Chi-square test (influenced by the sample size) was conducted. Second, the test proposed by Cheung and Rensvold [117,118] (with the Gaskin plugins [119] to verify if the evaluations given the subjects varied based on their national cultures, was conducted. Based on this, valid multilevel comparisons could be made between nations with equivalent (or invariant) psychometric measures and properties (for which the data needed to be standardised) [120–125].

To run this analysis, the following were compared: (a) the change shown in the Bentler comparative fit index (ΔCFI) between a general and a restricted model, and (b) the results of Equation (1), using as input the critical ratios, the regression weights and the standard errors (SE). For this, Gaskin's [126] Stats Tools Package ("Group Differences" tab) was used; this obtained the Z-scores corresponding to the T-values. If the ΔCFI is greater than 0.01, the less restrictive restricted model is accepted and the other rejected; and if the change in the CFI is equal to, or less than, 0.01, all restrictions are deemed to be sustained [127] (p. 20).

Equation (1). Formula to identify the differences in means and obtain T-values

$$t = \frac{\text{Path}_{\text{sample\_1}} - \text{Path}_{\text{sample\_2}}}{\left[\sqrt{\frac{(m-1)^2}{(m+n-2)} \times \text{S.E.}^2_{\text{sample1}} + \frac{(n-1)^2}{(m+n-2)} \times \text{S.E.}^2_{\text{sample2}}}\right] \times \left[\sqrt{\frac{1}{m} + \frac{1}{n}}\right]} \quad (1)$$

Path (sample 1): Non-standardized regression coefficient group 1; Path (sample 2): Non-standardized regression coefficient group 2; m: sample size of group 1; n: sample size of group 2; S.E 1: Standard error of sample 1; S.E 2: Standard error of sample 2. Source: [128].

At this point, an adjusted model was established based on the indicators proposed by Del Barrio and Luque [129]. Having adjusted the model, the SEM and the subsequent multi-group SEM were estimated. This last process was carried out with multi-group comparisons using AMOS's multigroup function, and a *t*-test of equality of means employing the Z-scores test of the Gaskin tool [119]. To determine if there were differences between the analysed countries, the previous procedure allowed the adjusted common model to be used to implement a multilevel comparison between the nations, as suggested by De Mooij [86] (p. 657); the country comparisons were made in pairs, that is, between the US and the UK, between the US and SA, and between the UK and SA. Hofstede's cross-cultural individualism dimension—IDV—allowed us to divide the countries into two groups: high individualism, HIDV, countries with scores between 67 and 100, that is, the US (91 points), and the UK (89), and medium individualism, MIDV, for SA (65) (with AMOS's 24 multigroup function) (Section 5.4). With this information, the hypotheses were validated using Dr Gaskin's coefficient differences tool and the comparison between medium- and high-individualism countries.

5. Data Analysis and Discussion

5.1. Basic Descriptive Analysis

At present, as expected, the data show more traditional (92.9%) than clean fuels (7.1%) are used in heating systems (Table 2). This may be due to various reasons: resistance to change [39]; the human tendency to maintain the status quo [130]; ignorance of clean technologies and their benefits [51]; and, at the diffusion stage, consumers may encounter higher acquisition costs [131,132].

Table 2. Respondents' current heating systems.

	Energy Technology	**Sample**	**%**
Traditional or fossil fuels	Electric heating system	190	44.7
	Heat pump	20	4.7
	Gas boiler	134	31.5
	Oil boiler	15	3.5
	Fuel boiler	10	2.4
	Others	26	6.1
Clean Systems	Biomass boiler	9	2.1
	Photovoltaic panels	16	3.8
	Others	5	1.2
	Totals	425	100

Source: Created by authors.

The respondents gave their respective behavioural intentions, that is, to continue using their current domestic heating systems, to convert to other systems, or even to stop using home heating systems (see Table 3). Where subjects had decided to convert to environmentally-friendly systems, as indicated by Sopha and Klöckner [39], this may be because they already exhibit pro-environmental behaviours; this is confirmed through SEM.

Table 3. Respondents' future behavioural intentions.

Current Technology	Future Behavioural Intention	Sample	%
From Traditional to:	Biomass	30	7.06
	Solar	181	42.59
	Other clean systems	36	8.47
	Continue using	137	32.24
From Biomass to:	Solar	2	0.47
	Continue using	7	1.65
From Solar systems to:	Biomass	1	0.24
	other clean systems	1	0.24
	Continue using	14	3.29
From other clean systems to:	Solar	2	0.47
	Traditional systems	1	0.24
	Continue using	2	0.47
	Stop using heating	11	2.59
	Totals	425	100

Source: Created by authors.

5.2. Reliability and Validity of the Measurement Scales

To test the validity of the PB construct items, the four categories of the NEP proposed by Van Rijnsoever and Farla [55] were initially taken into account. However, in this research context, when performing an EFA with the maximum likelihood extraction method and Oblimin rotation with Kaiser normalization, only two dimensions were obtained (NEPA and NEPB); these explained 53.83% of the total variance for NEPA (KMO = 0.6863; BTS = 0.00 < 0.05 gl. = 3) and 51.95% for NEPB (KMO = 0.669; BTS = 0.00 gl. = 3) (Appendix C). The other constructs were considered one-dimensional. The KMO value (0.849) and BTS value (p = 0.000) for ATRs also confirmed the suitability of factor analysis for summarizing the data of the original variables (Appendix B). The KMO value was within the suggested limit (approximately 0.70) for ATT, while the BTS was below the reference value (p = 0.00). While the ATT2 item showed fairly low commonality, it was included in the CFA (Appendix A). The composite reliability indicators (CR) and the average variance extracted (AVE), necessary for the evaluation of the discriminant validity are listed in the nextsection.

5.3. Measurement Model and Analysis of Factorial Invariance

As Mardia's multivariate test showed multivariate non-normality, with a Kurtosis value > 70 (Kurt = 136.823; Critical region = 38.38), it was determined that a ULS procedure measurement model would be more appropriate, based on the thresholds established by Del Barrio and Luque [129] for the indicators of goodness of fit (>0.90) and the root mean square residual (RMR: 0.043 < 0.08) (Table 4).

Table 4. Indicators of overall model fit for the unweighted least squares (ULS) measurement model.

Model	RMR	NFI Delta1	RFI Rho1
Model	0.043	0.972	0.964

RMR: Root Mean Square Residual; NFI: Normed Fit Index; RFI: Relative Fit Index. **Source:** Created by authors.

The composite reliability value (CR > 0.70) complied with the suggestion of Del Barrio and Luque [129], so the model satisfies the fundamental assumptions. The AVEs returned values above the threshold (0.5) recommended by Malhotra and Dash [133], with the exception of ATR, which gave a value close to the threshold (0.47). However, these authors argued that this threshold is very strict and suggested that the composite reliability values should also be taken into account. Similarly, as the inter-construct correlations of the different factors are less than the square root of the AVEs (see values on the main diagonal at Table 5), discriminant validity is verified in accordance with Fornell and Larcker [134].

Table 5. Measurement model measures of reliability and discriminant validity.

	CR	AVE	NEPA	NEPB	ATR	ATT
ATR	0.841	0.468	**0.684**			
NEPA	0.773	0.533	0.417 **	**0.730**		
NEPB	0.762	0.522	−0.073 **	0.331 **	**0.722**	
ATT	0.799	0.570	0.576 **	0.472 **	−0.064 **	**0.755**

Significance of Correlations: * $p < 0.050$. ** $p < 0.010$. *** $p < 0.001$. **Source:** Created by authors.

All the basic assumptions of the measurement model proposed for the three countries (RMR: 0.057; RFI: 0.939; NFI: 0.951) were satisfied and the configural invariance was verified. It was also verified that there was no invariance in the measurements of the general configuration between the three countries analysed (Table 6).

Table 6. Invariance test based on the Chi-square test.

Model	DF	CMIN	*p*-Value
Measurement weights	30	301.851	0.000
Structural covariances	42	647.041	0.000

Source: Created by authors.

As the previous test is influenced by sample size, a ΔCFI was performed by subtracting the CFI from the unrestricted model (0.843) and the CFI from the restricted model (0.739), accepting the restrictive model (ΔCFI = 0.104 > 0.01). On this basis, we went on to determine, using the Gaskin tool [126], which paths or coefficients were different in the base measurement model. This procedure showed that there were no differences in the comparisons of the UK vs. US and UK vs. SA, but there were in the US vs. SA (Table 7).

Table 7. Statistical differences in observable variables between the US and SA.

Observable Variables			US		SA		Z-Score
			Estimate	P	Estimate	P	
FUR	←	ATR	0.543	0	0.49	0	−0.607
IAQ	←	ATR	0.586	0	0.511	0	−0.89
FSS	←	ATR	0.653	0	0.508	0	−1.528
EFF	←	ATR	0.529	0	0.565	0	0.437
TIM	←	ATR	0.624	0	0.687	0	0.645
EUE	←	ATR	0.601	0	0.675	0	0.768
NEP2	←	NEPA	0.779	0	0.828	0	0.406
NEP3	←	NEPA	0.873	0	0.573	0	−2.733
NEP10	←	NEPA	0.742	0	0.51	0	−2.01
NEP6	←	NEPB	0.822	0	0.626	0	−1.154
NEP7	←	NEPB	0.929	0	0.66	0	−1.701
NEP8	←	NEPB	1.193	0	1.095	0	−0.51
ATT1	←	ATT	0.784	0	0.478	0	−3.083
ATT3	←	ATT	0.776	0	0.657	0	−1.187
ATT4	←	ATT	0.71	0	0.598	0	−1.141

Note: NEP3 and ATT1 were not taken into account to reach invariance between countries, due to the statistical difference found in this relationship. **Source:** Created by authors from [126].

The foregoing led us to choose a common model suitable for the three countries (RMR: 0.057 < 0.080; NFI: 0.951, GFI: 0.989 and AGFI: 0.986 > 0.90), which fits the data correctly (see the standardized coefficients of the SEM model, by country, in Table 8). This allowed multigroup tests to be carried out for the countries separately and obtained adequate goodness of fit indicators (RMR: 0.079 < 0.08, RFI: 0.915 and NFI: 0.919 > 0.90).

Table 8. Statistical differences in the relationships between countries.

Relationship between Constructs				US		UK		SA		US vs. UK	US vs. SA	UK vs. SA
				SC	*p*-Value	SC	*p*-Value	SC	*p*-Value	Test of Difference of Means (Z-Score)	Test of Difference of Means (Z-Score)	Test of Difference of Means (Z-Score)
H1	ATT	→	INT	0.40	0.005	0.609	0.007	0.195	0.469	1.170	−0.299	−1.039
H2	NEPA	→	ATT	0.368	0.002	0.606	0.000	0.137	0.381	0.613	−2.073	−2.496
	NEPB	→	ATT	−0.2	0.033	−0.302	0.042	−0.076	0.517	−0.274	1.453	1.524
H3	NEPA	→	INT	0.003	0.001	−0.55	0.018	0.005	0.969	−2.078	0.008	2.198
	NEPB	→	INT	0.209	0.033	0.507	0.002	0.147	0.158	1.603	−0.831	−2.262
H4	ATR	→	ATT	0.39	0.000	0.069	0.649	0.725	0.000	−2.025	−0.155	2.076
H5	ATR	→	INT	−0.032	0.796	0.125	0.361	−0.088	0.719	0.854	−0.831	−0.846

SC: Standardised coefficient SEM model, by country. **Source:** Created by authors from [126].

5.4. Results of the Cross-Cultural Analysis

The results of the multigroup analysis in the structural model are presented below (Table 8).

It can be seen that ATT had a positive impact on INT, and differs based on country (H1). A favourable attitude was found towards renewable energy-based heating systems in both the US (p = 0.005) and the UK (p = 0.007), that is, ATT was a key predictor of the subjects' sentiments regarding sustainable behaviour, as it had a direct positive effect on INT in these countries, which is in line with the theory of planned behaviour (TPB; [135]). However, this relationship was not significant for SA (p = 0.469). This confirms that the effect of ATT was not the same for the US, UK and SA, that is, the consumers demonstrated different predispositions towards the adoption of domestic biofuel-based heating systems based on the country where they live (ZUS vs. UK = 1.170; ZUS vs. SA = −0.299; ZUK vs. SA = 1.039).

PB (composed of NEPA and NEPB) positively influences ATT in the US and UK, and its influence on INT is different in the three countries (H2), with *p* values lower than 0.05, while for SA these relationships were not significant. Thus, it was found that the influence of PB on ATT differs significantly between the three countries, in particular, in the effect of both NEP scale dimensions (NEPA → ATT: US vs. UK = 0.613; US vs. SA = −2.073; UK vs. SA = −2.496 NEPB → ATT: US vs. UK = −0.274; US vs. SA = 1.453; UK vs. SA = 1.524).

Taking this into account, it was shown that PB had an indirect effect on INT through ATT in the US and the UK (H3); the PB-INT relationship is different for each country. It follows that PB has a positive relationship with INT in both the US and the UK as, when indirectly relating NEPA and NEPB with INT, it was shown, as statistically significant coefficients were found, that PB has an indirect effect on INT through ATT; for SA, these relationships did not show a marked effect (PB → INT). These results are consistent with studies in other contexts, such as Kaiser et al. [44], who proposed that environmental attitude was an effective predictor of ecological behaviour; Michelsen and Madlener [136], who verified the influence of preferences about RHS-specific attributes of residential heating systems, such as protection and environmental benefits in decisions to convert to clean systems in German homes; and Van Rijnsoever and Farla [55], who showed that environmental awareness and environmental attitudes are related to pro-ecological behaviours. In addition, it was confirmed that the consumer's perceptions about fuels differed significantly between countries (NEPA → INT: US vs. UK = −2.078; US vs. SA = −0.008; UK vs. SA = 2.198. NEPB → INT: US vs. UK = 1.603; US vs. SA = −0.831; UK vs. SA = −2.262).

ATRs were shown to have a positive impact on the formation of ATT in the US and SA, but for the UK this relationship did not present any statistical significance ($p = 0.649$; H4), thus, it is not influential there. It follows that, where ATRs might exert greater influence on ATT, INT to convert will not necessarily increase, because ATRs do not have an indirect effect on INT through ATT (H5). This allows us to ratify the findings of Lillemo et al. [66] and Sopha et al. [65] about the importance of ATRs in consumers' decision-making processes in terms of attitude for, or against, the use of new systems in the domestic environment, but not for behavioural intention. It was affirmed that there are important differences between the US and the UK, and between the US and SA, in consumers' perceptions of fuels, in terms of the relationship of ATRs with ATTs (Z-score = −2.025; 2.076); but not between the UK and SA, where the Z-score is −0.155 (ATR → ATT: US vs. UK = −2.025; US vs. SA = −0.155; UK vs. SA = −2.076). Finally, it should be noted that, in relation to INT, perceptions based on ATR differ (ATR → INT: US vs. UK = 0.854; US vs. SA = −0.831; UK vs. SA = −0.846).

Finally, the RQ is answered by observing the influence of Hofstede's individualism—IDV—as a moderating factor in the relationships of the structural model; this shows how the variable affects individuals' behaviours, or habits, in the two groups, HIDV and MIDV. Table 9 shows the statistical significances and differences within each group.

Table 9. Moderation analysis based on individualism (IDV) scores.

Proposed Moderating Effects on the Relationship between Constructs			Comparison of Groups				*t*-Test of Difference of Means (Z-Score)
			MIDV		HIDV		
			Estimate	*p*-Value	Estimate	*p*-Value	
NEPA	→	ATT	0.256	0.000	0.135	0.135	−1.055
NEPB	→	ATT	−0.127	0.026	−0.080	0.259	0.516
ATR	→	ATT	0.228	0.000	0.368	0.000	1.351

Source: Created by authors from [126].

MIDV and HIDV countries show different relationships between PB and ATT, and ATRs influence ATTs at both cultural levels. Similarly, as shown in the data in Table 9, it is evident that IDV has a moderating effect on previously-hypothesized relationships. It was found, also, that ATRs influence ATT, both in HIDV and MIDV countries, because they are statistically significant at both levels

(p = 0.000 < 0.05; T = 1.351 < 1.96). This seems to confirm the findings of Cyr et al. [93], who proposed that more individualistic societies prioritise individual over group interests.

On the other hand, NEPA and NEPB influenced ATT in the MIDV country (p = 0.000; p = 0.026, respectively), but not in the HIDV countries (p = 0.135; p = 0.259, respectively), although the Z-score shows no differences (NEPA: T = 1.055 < 1.96; NEPB: T = 0.516 < 1.96). These results are consistent with Waldman et al. [95], Park et al. [91] and Tata and Prasad [92], who showed that collectivist societies, which put group interests first, are more likely to believe in the importance of sustainability. However, the results contrast with Katz, Swansons and Nelson [137] and Husted [90]; these authors found that environmental-interest group activity seemed to be much more widespread and diverse in individualistic than in collectivist cultures. That is, countries with high-individualistic tendencies have greater social and institutional capacity to respond to environmental problems and to adopt the environmentally-friendly technologies that solve them.

6. Conclusions, Implications, Limitations and Future Lines of Research

The results of this cross-cultural analysis showed that the cultural variable individualism has a moderating effect on the relationships between the constructs analysed: Attitude, pro-environmental behaviour and perceived attributes toward intention to convert from fossil fuels to biofuels in residential heating systems; it was, indeed, empirically confirmed that there are intercultural differences in the degree of importance given to them in support of environmentally-sustainable development as an energy strategy.

It was corroborated that, in less individualistic cultures, such as South Africa, the cognitive beliefs that consumers have in favour of pro-environmental behaviours create a greater probability that they, as users of heating devices, will convert to cleaner systems, as these exert a positive effect on attitude towards conversion to this kind of technologies; the opposite is the case with highly individualistic countries, such as the US and the UK. However, with regard to the perceived attributes of heating technologies, such as efficiency, availability of the appropriate fuel, ease of use, and others, provided by the equipment, it was shown that the positive or negative perceptions that users have at both cultural levels will activate beliefs, or thoughts, that will influence for, or against, their residential adoption intention.

The study also identified that, in the US and UK, the attitude factor is positively influenced by the pro-environmental behaviour of individuals, and in the US and SA by perceptions of the technological attributes of bio-thermal systems. In turn, it was shown that, while a positive attitude towards sustainable domestic heating systems had a positive impact on intention to convert to biofuels in all three countries, the effect was different in each case. Thus, it would be sensible to consider these constructs in the modelling of conversion to, and adoption of, clean systems. In any case, it is recommended that additional studies be conducted for SA, since the empirical results showed that, although these constructs have an impact, it is not significant.

The findings of this study are aimed at local and global institutions and authorities, given that the results contribute to the knowledge of consumer behaviour regarding the conversion to, and adoption of, clean heating technologies. The results highlight the role of individuals in environmental sustainability because they show that their contributions can mitigate climate change [17], either through their participation in the form of communal heat generation and supply to public energy networks or through reducing their use of fossil fuels, by converting to domestic biofuel-based domestic heating. Similarly, national governments might take into account the moderating effect of culture when developing policies or strategies to increase the rates of conversion and adoption of bio-thermal systems in individualist countries. Governments and businesses should focus their advertising campaigns on increasing knowledge of renewable energies and on promoting environmental sustainability in homes through technological changes to heating systems.

In short, understanding what drives the acceptance and domestic use of these technologies in different countries can help in the development of global environmental change strategies to maximize the use of the technologies and support the fulfilment of sustainable development goals (SDGs).

In addition, this understanding will help the different social actors make better decisions about the diffusion and commercialization of sustainable thermal alternatives, to take into account cultural differences to adapt offers and messages to the needs and perceptions of high- or medium- individualist markets, and to formulate more effective penetration strategies in the context of cross-cultural marketing.

In closing, regarding the limitations of the present study and future lines of research, it should be noted that the consumer behaviour approach has been implemented in this work. However, other perspectives can be used to analyse the intention of converting residential heating systems to biofuel. Among these perspectives, there are those related to the technological management of innovation where the adoption process is taken into account from the perspective of the user adopter and their influence on other consumers (networks) and neuromarketing.

In this line, the first limitation is that the behaviour analysis of individuals' adoption and acceptance of biofuel-based heating technology systems is a multi-elemental process. Although the model is sufficiently parsimonious to explain intention to convert to domestic bioenergy home heating, it could be extended to include other variables, such as level of satisfaction with current systems, perceived behavioural control, subjective norms, and the sources of environmental information, among others.

A second limitation refers to the decision strategy that consumers make in the dynamic process of technology adoption within the perspective of technological management of innovation's framework. Within this management, the "takeoff in sales" concept, which implies a sales start-point that appears as a transition between the introduction and the growth stage of a new product, according to the diffusion maturity curve of a certain technology. Likewise, authors suggest carrying out the additional categorisation of the technological users who follow the innovation-decision process as generalized by the Diffusion Theory by Rogers [22]. This author classifies the adopters into five categories: innovators, early adopters, early majority, late majority and laggards. These categories provide a common language for innovation researchers who take into account the internal characteristics and factors of individuals [138].

On the other hand, regarding the diffusion models that are mainly driven by external factors such as the price and quality changes, it is important to consider the following categories suggested by Young [139]: (1) Contagion, in which the adoption of innovation by individuals is carried out once they meet another individual who has already adopted such technology, (2) Social threshold, in which the adoption takes place when enough individuals in the group have previously done so, (3) Social learning, which indicates that the subject adopts after other previous adopters have been able to verify that the innovation is beneficial to them; knowledge on innovation is extracted from the literature on marketing, sociology and psychology respectively [139] (p. 1900).

The previous concepts of technological diffusion may be clarified with a future line of research by giving dynamism to the measuring model formed by the relationships of the internal or external factors that influence consumer behaviour in a specific and static scenario, such as the consumer behaviour that was applied in the present study. This process can be executed, among others, through a multigroup analysis with SEM, as it was done with the moderating variable "culture" in the present work. This is done by generating comparison hypotheses among groups with the influence of other moderating factors that allow taking into account the phases, with the constant rhythm of the maturity curve in the diffusion of a technology (S-curve) and the decision process that each consumer goes through individually, according to their characteristics and the influence of their social network, either to give a reason for their own judgment or to make a decision [140].

Likewise, to dynamize the adoption behaviour analysis, it can be modelled and simulated in heterogeneous consumers of a dynamic social network that involves social learning, contagion of innovations, space, time, diffusion, price and the adoption curvature, among others. This can be done through a Consumat model, a simulation of real systems, or if it is an individual approach, it can be done through agent-based modelling (ABM) [141].

A third limitation relates to resistance to change [142] (p. 275). Lee [143] pointed out that this is a normal response in individuals, but most researchers have not considered subjects' unconscious responses to technological change and, therefore, no attention has been paid to the consumer resistance that could unconsciously be limiting their intention to convert. This resistance is explained by anthropological factors and by the contexts in which each person grows, and also by the perceptual and cognitive mechanisms that cause him/her to continue to use certain technologies [142] (p. 275).

Finally, in the present study, the fieldwork used an instrument that measured only the conscious responses of individuals to certain cognitive, affective and behavioural variables; future research should consider individuals' subconscious reactions, through the application of neuroscientific techniques, to specific stimuli which might induce particular behaviours.

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Appendix A

Table A1. Factor loading for ATT.

Variable	Items		Communalities	Factor Loadings
Attitude towards renewable energy-based heating systems **KMO = 0.699** **BTS = 0.00** **Cronbach's *alpha* = 0.798** **Total variance = 57.229%**	ATT1	using them goes with my lifestyle, therefore, it´s consistent with the way I think I should live my life	0.490	0.700
	ATT3	using them would be consistent with my own personal values	0.711	0.843
	ATT4	using them fits the way I see the world	0.526	0.725

Source: Created by authors.

Appendix B

Table A2. Factor loading and communalities for ATR.

Variable	Items		Communalities	Factor Loadings
Technology Perceived attributes **KMO = 0.849** **BTS = 0.00** **Cronbach's *alpha* = 0.839** **Total variance = 46.828%**	TIM	Time perceived	0.544	0.737
	IAQ	Indoor air quality	0.435	0.659
	EFF	Efficiency	0.516	0.719
	EUE	Effort required to use the equipment	0.496	0.704
	FSS	Fuel supply security (price and availability)	0.458	0677
	FUR	Functional reliability	0.361	0.601

Source: Created by authors.

Appendix C

Table A3. Factor loading and communalities for pro-environmental behaviour (PB).

Variable	Factors	Items		Communalities	Factor Loadings
Pro-environmental behavior (PB)	NEP A KMO = 0.686 BTS = 0.00 Cronbach's *alpha* = 0.772 Total variance = 53.83%	NEP3	If things continue on their present course, we will soon experience a major ecological catastrophe	0.399	0.742
		NEP2	Humans are severely abusing the environment	0.433	0.813
		NEP10	The balance of nature is very delicate and easily disturbed	0.307	0.635
	NEP B KMO = 0.669 BTS = 0.00 Cronbach's *alpha* = 0.752 Total variance = 51.95%	NEP7	The balance of nature is strong enough to cope with and recover from environmental impacts	0.547	0.739
		NEP8	The so-called "ecological crisis" facing mankind has been greatly exaggerated	0.673	0.820
		NEP6	Humans were meant to rule over the rest of nature	0.339	0.582

Extraction method: maximum likelihood. The rotation has converged in 4 iterations inverse items. **Source:** Created by authors.

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