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Student Energy-Saving in Higher Education
Tackling the Challenge of Decarbonisation

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Structured Abstract

Purpose:
This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in higher education settings.

Methodology:
We used a validated energy literacy survey to assess undergraduate students' attitudes and behavioural intentions towards energy-saving in two countries (Brazil and Belgium). The questionnaire, administered online, comprised 23 Likert scale questions and 3 questions eliciting socio-demographic information. Results were analyzed using a linear regression model and compared with previous research using the same energy literacy instrument.

Findings:
The research identified three dimensions of sustainable attitudes: Citizens' role, Scientists' role, and Government's role, explaining 65.5% of respondents' energy-related attitudes. Three dimensions of sustainable behaviours were identified, explaining 64.5% of energy-related behavioural intentions: Consumption of eco-friendly products, financially driven behaviours, and household energy saving. The linear regression model identified Scientists' Role, consumption of eco-friendly products and financially driven behaviour as the key predictors of student energy use. Differences between the two contexts also emerged.

Originality:
Student attitudes and behavioural intentions towards energy are an important element of campus decarbonisation and can act as a catalyst towards a carbon-free society. Although energy literacy research has been undertaken in the US and UK, this research is the first of its kind for Belgium and Brazil and the mode of analysis - using a linear regression model - differs from the earlier work, offering a novel methodological approach.

Keywords: Energy literacy; Decarbonisation; Campus

Article classification: Research paper

Student Energy-Saving in Higher Education: Tackling the Challenge of Decarbonisation

1. Introduction.

1.1. The energy problem

Demographic growth and increasing natural resource exploitation are environmental problems that worsen social issues such as health problems, extreme poverty, and social inequality (Pérez and Frank, 2019). With energy demands rising, and high levels of fossil fuel use, greenhouse gases in the Earth's atmosphere continue to increase, and CO_2 is currently at nearly 412 parts per million (ppm) and still rising. This represents a 47% increase since the beginning of the Industrial Age (Kappelle, 2020). According to the latest IPCC report (2021), 'human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years' (SPM-7). This is a crucial issue for humankind that requires an urgent response.

In Brazil, energy consumption was 16,325 KWh/p in 2019, while in Belgium, consumption was 65,303 KWh/p per person. Compared to 2018, energy consumption increased by 2.22% in Brazil and 4.79% in Belgium (Ritchie, 2021a). Concerning the share of primary energy from renewable sources in 2019 (including hydropower, solar, wind, geothermal, bioenergy, wave, and tidal), Brazil obtains 45.02% of energy from renewable sources, whereas Belgium uses only 6.94% renewables (Ritchie, 2021b).

Energy use in buildings represents 6.5% of direct and 12% of indirect emissions of CO_2 worldwide. To be successful in the transition towards a Post Fossil-Carbon Society, there is a need to reduce this type of energy consumption, as well as to minimize greenhouse gas emissions (EU, 2020; IPCC, 2021). The 'Energy Performance of Buildings Directive' in Europe required all new buildings to be nearly zero-energy by the end of 2020 (EU, 2020). However, additional efforts must be made for existing buildings as only about 1% of the building stock is renovated each year (Magrini *et al.*, 2020). In Brazil, since 2007, the certification body of the Leadership in Energy and Environmental Design (LEED) is the Green Building Council (GBC), which has already received 1,400 enrolments and issued 552 LEED certificates in commerce, industry, and services (UpperSolar, 2020). In both contexts, more work will be needed to meet challenging CO_2 reduction targets.

1.2 Energy and the Sustainable Development Goals.

An increasing number of universities and other Higher Education Institutions (HEIs) are seeking a Sustainable Development agenda for the future (Leal Filho et al., 2019). Historically, HEIs have played a key role in transforming societies, educating decision-makers, leaders and entrepreneurs (Nejati and Nejati, 2013). Their contribution to Energy Efficiency (EE) goals can be substantial beyond the facilities management realm in promoting individual action in staff and students, and undertaking research leading to policy changes. With the introduction of the Sustainable Development Goals (SDGs) (UN, 2015), there is now a clear structure to focus on, and the SDGs have become progressively more established in higher education (HE), frequently referred to in policies and curricula as students increasingly expect a sustainability focus. Engaging with the SDGs can offer benefits to institutions by demonstrating impact, capturing demand for sustainability education, building new partnerships, and accessing new funding streams. Education and research are explicitly recognized in several of the SDGs; thus HEIs, with their broad remit around the creation and dissemination of knowledge and their unique position within society, have a pivotal role to play in their achievement.

Higher Education increasingly needs to equip students with the necessary skills to comprehend and solve wicked problems (Weber *et al.*, 2021). This requires an interdisciplinary approach with new solutions for the economy and society, hence initiatives can often be linked to multiple SDGs. For example, EE projects can obviously have an impact on SDG 7 (sustainable energy), but are also likely to impact SDG 4 (education) and SDG 3 (wellbeing). There is an increasing focus on linking the educational aspects of sustainability with campus developments – encouraging students to undertake projects concerning use of energy in buildings for example. Educational buildings have enormous potential for improvements in energy efficiency. They represent a large volume managed by one single owner (in contrast with the private market). Moreover, they offer a forum to involve various stakeholders (facility managers, visitors, students, and teaching and research staff) with diverse backgrounds to create, support, and marshal evidence for energy conservation. In short, energy efficiency has a key role to play in the move towards using the campus as a living lab (see Franco et al., 2018; Mazutti et al., 2020) – combining student learning with carbon reduction aspirations.

1.3 Aims and Context of the Research

This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in HE. The research was conducted at two universities, PXL University of Applied Sciences in Belgium and the University of Caxias Do Sul in Brazil. It offers novel insights into how students understand energy, their attitudes towards it, and their energy-saving behavioural intentions. The survey has been previously undertaken in the UK, Portugal, and China (Cotton *et al*., 2016a; 2021). Its use in another European HEI offers the possibility to extend the reach of this survey, and by involving the University of Caxias Do Sul, the first comparison with a Latin American country is possible. This choice is no coincidence as, in 2019, Brazil was the first country in Latin America that is not a member of the International Energy Agency (IEA) to complete the Agency's efficiency indicators questionnaire. Brazil is a priority country in the Agency's Clean Energy Transitions Program (IEA, 2019), and thus offers an exciting new context to explore this issue.

2. Theoretical background and literature review.

2.1 Energy Literacy in Higher Education.

A significant literature on sustainable universities has been emerging over recent years as HEIs recognize the necessity to be seen as leaders in this field, and researchers increasingly turn their attention to their own institutions and sector. Moving beyond the early attempts at campus greening to embed and include student learning in sustainability teaching and research endeavours has proved challenging but rewarding where efforts have been successful. Despite varied national contexts, universities worldwide have made some progress towards the sustainable university model as laid out by Sterling *et al.*, 2013. For example, the recent review by Findler *et al*., (2019) indicates a broad range of research indicating direct and indirect impacts on sustainability arising from the activities of HEIs - though largely in the form of case studies of individual institutions or subjects.

An essential mode of linking campus environmental developments with broader sustainability education has been through energy literacy (DeWaters and Powers, 2011). Originating in the US

through work by DeWaters and Powers (2011), energy literacy embeds cognitive, affective, and conative elements in a tripartite framework, including:

- knowledge and understanding about energy, its use, and impact on environment and
- attitudes and values, for example, on climate change and the significance of personal actions; and
- intentions/behaviours, for example, to promote energy conservation or to advocate change.

Energy literacy should "… empower people to make appropriate energy-related choices and embrace changes in the way we harness and consume energy." (DeWaters and Powers, 2011, p.1699). In other words, it is aimed at behaviour change – a theoretically contested area with several competing perspectives in the literature.

2.2 Behaviour change.

The literature on behaviour change motivators often refers to the Theory of Reasoned Action (Fishbein and Ajzen, 1975). This theory indicates that behaviour depends on pre-existing attitudes and subjective norms associated with the specific behaviour. It was later developed by Ajzen (1991) and renamed the Theory of Planned Behaviour which included an element of perceived agency. This idea has also been shown to be important in energy-saving behaviours, where students' sense of personal agency in terms of individual behaviour has been seen to be much stronger than their belief that they can influence others (Cotton *et al.*, 2016b). Notably, knowledge plays little role in these theories, and the widespread view has been that knowledge about sustainability issues is insufficient to prompt behaviour change (Blake, 1999; Kollmuss and Agyeman, 2002). Some research into behaviour change towards sustainability has taken a more expansive theoretical framing, using social models of behaviour change (e.g., Stern, 2000; Jackson, 2005). These posit that an individual's ability to change is influenced not only by their personal perspective but also by the surrounding infrastructure (e.g., bicycle lanes or recycling facilities) that supports or inhibits them from changing their behaviour. Social models of behaviour change include Social Practice Theory (Shove, 2010; Hargreaves, 2011) and Sustainable Transition Management (Rotmans *et al.*, 2001; Verbong and Loorbach, 2012). These are 'systems theory' approaches that aspire to changes to society rather than merely to individuals.

The way sustainability issues are framed may also have a significant impact on the likelihood of behavioural change. For example, research by Spence *et al.*, (2014) suggested that framing energy saving in terms of carbon dioxide reduction rather than money-saving could encourage behaviour change. However, other research has identified financial inducements as more effective than verbal encouragement when attempting to encourage 'green' purchasing (Lanzini and Thøgersen, 2014). Research into social marketing approaches to sustainability indicates that an unduly moralizing or fear-inducing message is ineffective in encouraging behaviour change and potentially unethical (French and Gordon, 2019), but that enhanced emotional arousal or engagement can prompt behaviour change (Jacobs and Harms, 2014). Roeser (2012) described emotions as the 'missing link' in encouraging pro-environmental behaviour change, and further evidence of the role of emotion in pro-environmental behaviour was found in experimental work by Morris *et al.*, (2019). A further concept of note is 'behavioural spillover' – which suggests that acting in a pro-environmental way may encourage people to engage in related pro-environmental activities as a protective response to avoid cognitive dissonance (Thøgersen, 1999). Barriers to behaviour change include inertia (habits are difficult to change) and lack of awareness of an issue (Hafner *et al.,* 2019). However, the habit

discontinuity hypothesis (Verplanken and Roy, 2016) suggests that a significant life change may prompt a re-evaluation of long-standing behaviour. Thus, for many students starting university may be an opportunity to make changes toward a more sustainable lifestyle.

2.3 Energy efficiency (EE).

Energy efficiency in HE can take multiple forms. Design of campus buildings, as well as behaviour change of the individuals that use them, are both important elements. In design terms, it is important to take account of the whole life cycle of a building, considering its carbon and material footprint (construction, renovation, retrofitting) (La Fleur et al., 2019). In terms of behaviour change, there is a need to consider technical, social, economic and educational aspects. Heating, ventilation, and air-conditioning (HVAC) is the primary source of energy consumption in most university buildings, and these are intimately inter-related with the actions of building users. Sanguinetti *et al*. (2017) stressed various energy efficiency goals in buildings: inspiring occupant participation, interpretation of the data, and improving comfort and energy efficiency. Kim *et al.* (2019) detailed the crucial role of facility managers in HE building EE projects. Whitney *et al.* (2020) mentioned the motivation, barriers, and leverage points to achieve an energy reduction for (commercial) buildings. In tandem with EE and energy flexibility, the introduction of renewable energy is an essential tool to realize a carbon-free society (*Blazquez et al.*, (2020).

There are various ways of trying to improve energy consumption in buildings, including the 'trias energetica' method which involves reducing demand, using renewable energy and limiting fossil fuel use as far as possible. An alternative is to utilize a Maintenance Energy Performing Contract (MEPC), which considers not only economic aspects but also incorporates comfort, maintenance, and energy reduction (*Bleyl et al*., 2019). Essential parameters for retrofitting (historic) buildings using an EPC were listed by Tantau (2020) – and they are mostly valid for other buildings. Education buildings have the advantage that they generally have one owner and deal with a large volume of users. Filho *et al.*, (2019) summarised different approaches to EE used by HEIs including pooling buildings to start a deep building renovation, combined with projects with a shorter payback time (Franco *et al.*, 2019 and 2020). Another critical topic is engaging with students, the next generation of leaders, whereby co-creation is both desirable and achievable in terms of building design and use (Franco *et al.,* 2020).

3. Methods and context

3.1 Sample.

The universities involved in this study are PXL University of Applied Sciences (Belgium) and University of Caxias Do Sul (UCS) (Brazil), with 754 students in total participating.

PXL University of Applied Sciences (PXL UAS) is a centre of expertise for innovation, creativity, and entrepreneurship. The institution organizes all activities starting from the quadruple helix model, i.e. the interaction between government, knowledge institutions, industry and society. Because all stakeholders are involved in this quadruple helix model, it is logical that the Energy Efficiency projects are given a more holistic and ecosystemic approach. In this way, such projects can contribute to the well-being of the user of the building (internal climate). Moreover, this building can be part of a healthy environment (external climate). By involving all these stakeholders, it becomes a co-creation process for the HEI in which professors, the business world and students

work together on assignments and realizations. In addition silos are broken down, there is a shift from linear to circular thinking (Health, 2021). It provides better supported solutions and a gain for the participants; students and business get to know each other better with a view to further professional collaborations, apart from the monetary and environmental gain in the Energy Efficiency project itself.

The University of Caxias Do Sul (UCS) is a centre of innovation, creativity, and entrepreneurship focusing on sustainability. UCS takes part in the ranking of the best universities globally (Times Higher Education) and for the second consecutive year ranked as the most innovative university in Brazil among the community and private universities and positioned as one of the 20 most entrepreneurial companies in the country. Research activities include 28 Masters and Doctorate courses, and the university is also responsible for the training of teachers and professionals with high levels of creativity, resulting in 113 patent registrations at the National Institute of Industrial Property (INPI). The Research and Postgraduate programme brings together professors in 17 Research Centres, 21 Innovation and Development Centres, and 72 Research Groups. The university has 800 laboratories on eight campuses, 92 of which are specific for research related to the provision of services or consultancies. (UCS, 2021). Given the proactive and problem-solving nature of entrepreneurial universities (Segers, 2020), it can be argued that these types of universities have a natural tendency to grapple with societal issues rather than merely engaging in activities that only generate an economic gain. According to Klofsten *et al*. (2019), an entrepreneurial approach will help university leaders to identify and deal with certain leadership challenges and strategic issues. One of the latter is the sustainable development agenda (Fig. 1). Moreover, grappling with societal problems is a two-way street. Apart from the apparent benefits societies garner from university engagement, universities gain advantages too.

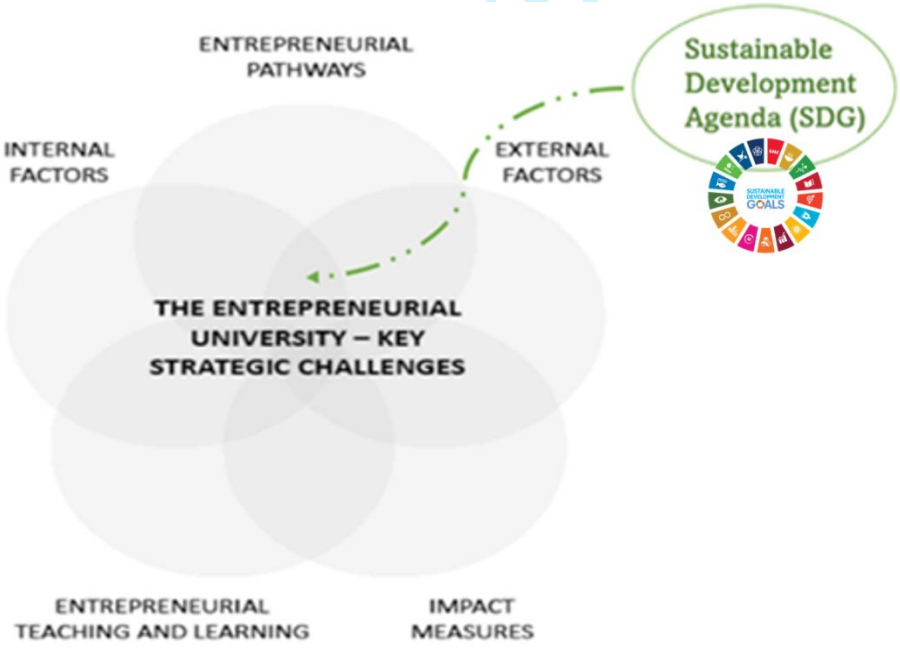

Figure 1 - Key strategic challenges of the entrepreneurial university (Klofsten et al., 2019 - adapted)

Table 1 Gender and age distribution

University	Gender	N (%)	Age	N (%)
Belgium	Male	155 (41.0 %)	20 or under	100 (26.5 %)
	Female	221 (58.5 %)	21-25	117 (31.0 %)
	Missing	1 (0.3%)	26-35	50 (13.2 %)
	Total	378 (100%)	36-47	48 (12.7 %)
			46-55	33 (8.7 %)
			Over 55	29 (7.7%)
			Missing	1 (0.3%)
			Total	378 (100 %)
Brazil	Male	214 (56.9%)	20 or under	105 (27.9 %)
	Female	158 (42.0 %)	21-25	158 (42.0 %)
	Missing	4 (1.1%)	26-35	71 (18.9 %)
	Total	376 (100%)	36-47	12 (3.2 %)
			46-55	2 (0.5 %)
			Over 55	0 (0%)
			Missing	28 (7.4%)
			Total	376 (100 %)

The sample consisted of 754 undergraduate students from Belgium (n = 378) and Brazil (n = 376). The demographics of student respondents are provided in table 1. Most participants in both institutions were under 25 years old, with the Brazilian university being more strongly weighted to younger students. At the Belgian university, most respondents were bachelor students (218 out of 378) but the survey was also carried out among the participants of after-training courses, which explains the slightly higher proportion of older students. The sample is balanced in terms of gender, with 50.7% female respondents, the Belgian sample being slightly female dominated and the Brazilian sample slightly male dominated. Brazilian students are from diverse fields of knowledge: engineering (35.2%) and exact sciences (23.3%), social sciences (29.9%), health sciences (10.6%), and arts and languages (1.0%). For Belgium, the students are also from diverse fields: technologies (31.7%), social sciences, economics, and communication (29.6%), exact sciences (2.8%), health sciences (20.3%), arts and languages (15.6%).

3.2 Survey and analysis

This study builds on the authors' existing work, exploring energy literacy amongst HE students (Cotton *et al.*, 2016 a & b). We explore participants' attitudes and behavioural intentions with different sustainability approaches using existing scales and validated instruments. The research involved an international team from the UK, Portugal, Brazil, and Belgium. The questionnaire was first translated into Brazilian Portuguese (for Brazilian respondents), Flemish, and English (for Belgian respondents), and then back translated to English to ensure the questions' readability and intelligibility. The original survey instrument contained 40 questions exploring energy knowledge, attitudes, and behavioural intentions and included a mixture of ranking, Likert-type scales, closed and open questions.

A version of the survey developed by Cotton was used in this study, with some modifications to ensure accurate translation. (The survey instrument itself is available here)[1] This survey has been used in previous research in the UK, Portugal, and Belgium (Cotton *et al*., 2016 a & b; Franco *et al.*, 2018) and in China (Cotton *et al*., 2021). The section on attitudes asked survey respondents to respond statements about their attitudes towards climate change, scientists, and energy efficiency, together with their feelings of agency regarding government and businesses' actions. The section on behaviours asked respondents about behavioural activities, such as paying more for environmental products or turning down heating in rooms. The same 5-point Likert scale was used for the affective and behavioural domains, and examples of individual and social actions were included. Higher scores on these scales generally denote more positive attitudes toward energy-related issues or more effective energy-saving behaviours.

The analyses were performed as mentioned below

(i) descriptive analysis;
(ii) factor analysis to identify the dimensions of attitudes and behaviour;
(iii) regression analysis to identify which dimensions are the most explanatory of energy use;
(iv) analysis of variance, to identify statistically significant differences between countries.

It must be stressed that this survey was undertaken before the pandemic. The survey was open for a long period, but responses tailed off after two months. The survey was made available to students via institutional webpages or direct emails from administrative staff. For ethical reasons, the students were told that the survey was about energy, which may have encouraged more knowledgeable students to respond. The authors are aware of the sample's limitations; however, the overall number of respondents in each institution was high, and respondents were broadly speaking representative of those in the whole institution.

4. Results and Discussion

In this section we present and discuss the descriptive statistics for each dimension of attitude and behavioural intentions, the factor analysis results (for attitudes and behavioural intentions), the tests of differences in means, and the linear regression model offering an explanation of students' use of energy. We explore similarities and differences between the two institutions, as well as comparing findings to previous research using the energy literacy survey.

4.1 Sustainable Attitudes Scale.

The internal reliability index of the Sustainable Attitudes scale, measured using Cronbach's alpha, was 0.600, representing a satisfactory internal reliability level (Hair *et al*., 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.613 (Bartlett's Sphericity Test ($p < 0.00$)), a result that points to the factorability of the data. The analysis employed Principal Component Analysis (PCA) with varimax rotation and listwise treatment for missing values. Factor analysis was performed in 4 iterations. The final model showed three dimensions of sustainable attitudes: Citizens' Role, Scientists' Role, and Government's Role (Table 2). The total explained variance was 65.522% with the Citizens' Role dimension explaining 23.560%, the Scientists' Role, 21.332%, and the Government's Role, 20.630%.

[1] https://www.researchgate.net/publication/341179747_Energy_Literacy_Survey_Debby_Cotton

Table 2. Factorial results for attitudes

Dimension	Items	Factor Loading	Mean	Standard deviation
Citizens' Role	A3 – I can influence what the government does about energy problems.	0.871	2.59	1.032
	A4 – I can influence what companies do about energy problems.	0.876	2.60	1.035
Scientists' Role	A6 - Scientists will find ways to solve energy problems.	0.895	3.40	1.019
	A9 - Climate change has been established as a serious problem and immediate action is necessary.	0.790	3.30	1.428
Government's Role	A10 - Climate change is caused by human activities related to using energy	0.758	3.80	0.863
	A8 - The government should have stronger standards on fuel efficiency of cars.	0.754	3.82	0.964
	A7 - More wind farms should be developed to generate electricity, even if they are located in scenic environments.	0.518	3.41	1.080

Note: 1-Strongly disagree, 2- Disagree, 3 Neither agree or disagree, 4-Agree, 5- Strongly agree

The Citizens' Role dimension (M = 2.59; SD = 1.850) includes the variables: (i) "I can influence what the government does about energy problems"; and (ii) "I can influence what companies do about energy problems". This dimension was the one that presented the lowest averages, which suggests that respondents are generally ambivalent or slightly disagree that they can influence government action. This finding has been reported in almost all contexts where the survey has been used. In the UK, students were consistently less confident about their ability to influence others than to engage in personal behaviour change: "the overriding story is one of limited agency, exacerbated by respondents' low incomes and perceived powerlessness" (Cotton *et al.*, 2016a, p. 894). In Portugal, students expressed somewhat stronger agency than those in the UK (Cotton *et al.*, 2016b), and in China, this was one of the most vital elements of the student response, perhaps reflecting a more collectivist culture (Cotton *et al.*, 2021). Similar results were found in Mulder *et al.* (2010), which analysed the learning outcomes of 500 students from five European Technological Universities concerning the sustainable development and the pedagogical approach adopted. The results demonstrate that students initially perceived sustainability mainly related to technological aspects, believing that technology can offer solutions to environmental problems and perceived little relevance of sustainability's social and behavioural aspects.

For environmental problems to be minimized and for an improvement in environmental quality to occur, changing individuals and society's behaviour is fundamental to improving environmental and life quality - this is an issue that requires an educational process and environmental awareness (Lozano *et al.*, 2019). The Scientists' Role dimension (M = 3.34; SD = 1.059) includes the variables: (i) "Scientists will find ways to solve energy problems"; and (ii) "Climate change has been established as a serious problem, and immediate action is necessary". This dimension had an average higher than 3.0, indicating that respondents believe in climate change and are confident about scientists' role in solving the climate crisis. All groups were considerably more likely to think that scientists will find solutions than that governments will act, which echoes the UK and Portuguese findings (Cotton

et al., 2016a and b), but the reverse was found in the Chinese sample (Cotton *et al.*, 2021). These results are in line with the study by Nejati and Nejati (2013), which also evaluated students' perception of the university's performance in creating partnerships with the government, non-governmental organizations, and the industry working towards sustainability. Leal Filho and colleagues (2015) showed that the government's role must go beyond financial support for universities, in encouraging universities to make education more flexible for sustainability and identifying opportunities in the green economy.

The third dimension, Government's Role (M = 3.67; SD = 1.991) includes the variables: (i) "Climate change is caused by human activities related to using energy"; (ii) "The government should have stronger standards on the fuel efficiency of cars."; and (iii) "More wind farms should be developed to generate electricity, even if they are in scenic environments". This dimension was the one that presented the highest averages, which suggests that respondents agree with the statements. Again, this echoes findings in the UK and Portugal (Cotton *et al.*, 2016b) but contrasts with China's findings (Cotton *et al.*, 2021), perhaps reflecting the more significant cultural similarity with the UK and Portuguese contexts of these groups of students.

4.2 Sustainable Behaviours Scale.

The internal reliability index of the Sustainable Behaviours scale, measured using Cronbach's alpha, was 0.620, representing a satisfactory internal reliability level (Hair *et al.*, 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.644 (Bartlett's Sphericity Test (p <0.00)), a result that points to the factorability of the data. The factor analysis employed the Principal Component Analysis (PCA) with varimax rotation and listwise treatment for missing values. Factor analysis was performed in 5 iterations. The final model showed three dimensions of sustainable behaviours (Table 3). A total explained variance was 64.543%; the Consumption of eco-friendly products explains 23.395%, Financially-driven behaviour 20.871%, and Household energy-saving 20.278%.

Table 3. Factorial results for behaviours

Dimension	Items	Factor Loading	Mean	Standard deviation
Consumption of eco-friendly products	B17 - Buy things that are likely to involve less energy or resource use.	0.823	2.35	0,822
	B18 - Pay a bit more for environmentally friendly products.	0.860	2.41	0.819
Financially driven behaviours	B19 - Avoid charging mobile phones overnight.	0.798	2.31	1.084
	B20 - Turn off the stand-by button of the TV set or switch appliances off at the plug.	0.766	2.60	1.117
Household energy saving	B13 - Turn off lights when they are not in use.	0.737	3.63	0.561
	B14 - Turn down the heat or air conditioning.	0.727	3.21	0.875
	B15 - Try to save water.	0.589	3.02	0.785

1-never, 2-infrequently, 3-frequently, 4-always

The ordering of these behavioural items from most to least popular is remarkably similar across student populations in a wide range of contexts in which the survey has been used. Turning off lights is almost invariably the most popular energy-saving activity by students, suggesting that this behaviour is almost ubiquitous and automatic. Behaviours that involve financial outlay are generally less popular with students, reflecting, at least in part, their limited financial position. Avoiding charging phones overnight also often rates as less popular and is somewhat controversial, particularly as phone technology improves to reduce the risk of power usage when fully charged. This pattern of responses can be seen in the Portuguese and UK respondents (Cotton *et al.*, 2016b) but not in the Chinese sample (Cotton *et al.*, 2021).

4.3 Linear regression analysis.

The relationship between the dimensions of attitudes and behaviours and the variable "When it comes to energy use, how would you describe yourself" was tested by linear regression, using the stepwise method (Table 4). The energy use variable (M= 2.77; SD = 0.891) was assessed on a scale of 1 to 5, with 1 for respondents who consider themselves low energy users and 5 for respondents who consider themselves high energy users. The results of the linear regression show that three dimensions in the model are significant for the use of energy and represent 20.3% (R2 = 0.203, p <0.05) of the overall use assessment: Scientists' Role, Consumption of Eco-friendly products, and Financially-driven behaviour. The Durbin-Watson test was employed to detect the presence of autocorrelation (dependence) in the residuals of a regression analysis (Hair *et al*., 2003). The model's test value (1.872) indicates that the residuals are independent (with a 95% confidence level).

In other words, the overall assessment of the use of energy depends significantly on the performance of these dimensions (Table 4). The model equation can be written as follows:

USE OF ENERGY = 0.210 + 0.381 * Scientists' Role – 0.150 * Consumption of Eco-friendly products – 0.139 * Financially-driven behaviour *{equation 1}*

Table 4. Linear regression model

Model	R	R Square	Adjusted R Square	St. Error of the Estimate	Durbin-Watson
1	0.391[a]	0.153	0.152	0.820	
2	0.435[b]	0.189	0.187	0.803	
3	0.454[c]	0.206	0.203	0.795	1.872

a. Predictors: (Constant), Scientists' Role

b. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products

c. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products, Financially-driven behaviour

The most important dimension in the assessment of energy use is "Scientists' role" (beta = 0.381; sig. 0.0000), which means that energy use increases with the belief that scientists will solve the energy problem and decreases as people consume more eco-friendly products and adopt more economy driven behaviours.

Table 5. Linear regression coefficients

Final Model	Unstandardized		Standardized	t	p
	B	Std. Error	Beta		
(Constant)	2.967	0.210		13.937	0.000
Scientists' Role	0.318	0.028	0.381	11.155	0.000
Consume of Eco-friendly products	-0.186	0.044	-0.150	-4.235	0.000
Economy driven behaviour	-0.234	0.059	-0.139	-3.953	0.000

4.4 Differences between Brazilian and Belgian respondents.

All dimensions showed significant differences for respondents from Brazil and Belgium. Only the Scientists' Role did not pass the homogeneity of variance test (Levene's test), but as the samples from Brazil (n = 376) and Belgium (n = 378) have sample' size variation of less than 10%, the homoscedasticity test does not affect the analysis of variance (Pestana and Gageiro, 2005). The ANOVA test allows us to conclude that there are significant differences between respondents from both countries for all dimensions of attitudes and behaviours.

Across all three attitudinal dimensions (Scientists 'role, Citizens' role and Government's role), Brazilian students scored more highly. Brazilian students expressed a strong faith in Science (F=529.938; sig=0.000), indicating that Brazilian students have a strong belief that scientists will find ways to solve energy problems and that climate change demands immediate action. Brazilian students also felt more strongly about the Citizens' role (F=197.333; sig=0.000), expressing a stronger sense of agency and a stronger agency to influence the government and companies' actions. And finally, they expressed stronger support for the government taking a role in energy issues (F=23.444; sig=0.000) – for example by bringing in stronger standards on fuel efficiency in cars. In terms of the behavioural dimensions, Brazilian's students were more financially driven (F=38.351; sig=0.000) overall. Belgian students showed greater propensity for consumption of eco-friendly products (F=7.745; sig=0.000) and household energy saving (F=273.939; sig=0.000). A possible explanation might be linked to the fact that the average age of participants was higher at the Belgian institution and that they may have lower expectations of third parties (75.6% of the Brazilian respondents were under 25 years old, while 57.6% of the Belgian respondents are in that age group). Moreover, the typical Belgian governance structures (federal versus regional level) will also not promote "belief in government". The third layer from the EU may increase the complexity still further and thus reduce the trust in the government as a third partner for the Belgian participants.

Table 6. Institutional differences

Dimension	Belgium		Brazil	
	Mean	SD	Mean	SD
Attitudinal dimensions				
Scientists' role	2.667	0.939	4.035	0.653
Citizens' role	2.178	0.790	3.026	0.852
Government's role	3.560	0.646	3.792	0.661
Behavioural dimensions				
Consumption of eco-friendly products	2.459	0.697	2.313	0.735
Financially driven behaviour	3.173	0.508	3.407	0.518
Household energy saving	2.922	0.731	1.984	0.817

Despite the scepticism illustrated by their attitudinal positions, the Belgian respondents scored quite highly on the behavioural dimensions. It is known that an individual's behaviour is not always consistent with their attitudes. Bael (2009) has previously shown that people exhibit varied behaviours in different contexts and under the influence of different external and internal factors and actions may or may not be consistent with their underlying attitudes. Sometimes an individual's behaviour is influenced less by their underlying attitudes than by the prevailing social norms. This could be an explanation for the Belgian behavioural dimensions being mostly higher than the Brazilian ones. There are significant current initiatives within the University (PXL) to include sustainability in their policies which may have had a positive influence on their students' behaviour in comparison with Brazilian students.

In addition, the World Values Survey (Halpern, 2005; Inglehart, 2014) indicates that, historically, Brazil has been among the nations with a low social capital level and a downward trend. Social capital can be understood as the systems of participation and reciprocity that involve community relations (Putnam, 1993). When social capital is less present, there is a tendency towards opportunism and selfish attitudes and behaviours since it implies that individuals can engage in the common good (Coleman, 1990; Inglehart, 2014). On the other hand, in Belgium, social capital levels are higher and tending to increase, showing a more communitarian spirit in attitudes and behaviours. However, further research would be needed to confirm this hypothesis. There are some interesting opportunities to explore the impact of personal, situational and behavioural variables on the relationship between attitudes and behaviour (Roberts *et al*., 2017). Analysing the cultural dimensions of both countries following the framework provided by Hofstede (2011) might also be informative in providing a better understanding of the differences between the countries and the ways in which they might influence individual behaviour. An analysis of the psychographics (e.g., lifestyles and values) would enrich future analysis.

In Brazil, not so many HEI (9) are active on the SDGs or agenda 2030, despite addressing sustainability practices (Pontelli et al., 2019), demonstrating a gap to be filled regarding sustainable development especially in public institutions. This collaboration and exchange of information between the EU countries and more specific with the Belgian PXL UAS can make a priority of Energy Efficiency for the University of Caxias Do Sul.

PXL UAS is the first SDG pioneer in Belgium and rather an atypic illustration. As the institution organizes all activities starting from the quadruple helix model, i.e. interaction between government, knowledge institutes, industry, and society. The quadruple helix approach illustrates the interaction with all stakeholders and the interdisciplinarity shows to all of them that Energy Efficiency projects incorporate economic benefits, as well as education, wellbeing, and community engagement, which improves the actions and interpretations of these stakeholders (including the students).

5. Conclusions

This research involved deploying a widely used, rigorously tested energy literacy survey in two novel contexts, and using a new analytical approach. Three elements of sustainable attitudes and three elements of sustainable behaviours have been identified, and a linear regression analysis used to develop an equation linking certain attitudes and behavioural dimensions to overall energy usage. This enhanced theoretical model of individual energy use offers an additional tool to explore energy literacy in future research and suggests that overall energy use is positively related to consumption of eco-friendly products and financially driven behaviour but negatively related to a strong belief in science, suggesting a possible over-optimism about the role of scientists in solving energy problems. This new insight emphasises the need for care to be taken in educational contexts to ensure that students understand that there is a role for individual action as well as scientific advance and government regulation in combating climate change. Differences between the two contexts also emerged, with Brazilian students being generally more optimistic about the role of scientists, citizens, and the government than those in Belgium. Perhaps reflecting students' different economic circumstances in the two countries, those in Brazil were more financially motivated, and the Belgian students showed a greater propensity for consumption of eco-friendly products and household energy saving. Notice that previous studies have reported that energy consumption was higher in Brazil, thus this could be a way Belgium students ameliorate the problem.

It is not clear that in either context, the attitudes and behaviours of respondents are sufficient to drive the level of change needed to avert the climate crisis. It is also necessary to take into account the influence of the surrounding infrastructure, and the impact of the theory of change in society. Echoing previous research in the UK and Portuguese context, this study notes the limited sense of agency felt by students both in Belgium and Brazil regarding influencing the actions of government or businesses. These are sobering findings, given the clear need for strong political action globally. There is also evidence that, like most of the students surveyed worldwide, the behaviours which were most undertaken were not those that save the most energy! Students in Belgium and Brazil, as with those in the UK and Portugal, were more likely to see turning off lights and other similar activities as playing a pivotal role, despite their limited impact on energy use overall. Findings differed significantly from the Chinese context, leaving this as an outlier where students had hugely different attitudes and behaviours towards energy saving – with the Chinese respondents indicating less positive attitudes towards energy saving and a lower likelihood of making individual behaviour changes, but having a greater trust in government to act (Cotton et al. 2021). Further research on cultural context, and the implications for energy saving and sustainability education would be extremely valuable.

In terms of the behaviour change theories discussed earlier, our research illustrates the importance of attitudinal variables in influencing behaviour change (as per the theory of reasoned action), but

also considers perceived agency (added into the theory of planned behaviour) as a mediating variable. This issue is complex and in a sense our research adds weight to the social theories of behaviour change in expanding this notion of agency beyond the individual and their own lifestyle to include their perception of being able to influence other bodies (government and companies). Looking more deeply still, we can observe a tension between the positive impact on behaviour change of feeling that one can influence others' behaviours (such as government and companies) and thus promoting forms of political and social action, and the negative impact of feeling that – as in this instance – scientists will be able to solve all the energy problems. There's a delicate balance to be found here between encouraging a trust in science – but without allowing people to externalise the responsibility for climate change mitigation onto another group (scientists). The precise ways and extent to which local subjective norms and available infrastructure in each setting impact on actual energy-saving behaviours would be worthy of further research.

This paper contributes to a broader debate on strategies for implementation of ESD (Education for Sustainable Development) and education for sustainability (EfS) by mapping arguments on competencies for SD and sustainability with a particular focus on higher education institutions. Our findings suggest that: (i) universities should focus on individual behavioural changes alongside teaching sustainability science (to reduce the risk that students rely on scientists to solve energy problems); (ii) governments should encourage public policies to raise awareness of the role of citizens in the sustainable use of energy; and (iii) universities should identify key elements for the construction of north-south cooperation proposals, such as capacity building programs for the dissemination of best sustainable practices. By identifying factors influencing students' perceptions of sustainability, and their energy saving activities, this study provides pertinent evidence for social researchers and university managers on ways in which the sustainable university ideal might be realised.

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Student Energy-Saving in Higher Education
Tackling the Challenge of Decarbonisation

Structured Abstract

Purpose:
This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in higher education settings.

Methodology:
We used a validated energy literacy survey to assess undergraduate students' attitudes and behavioural intentions towards energy-saving in two countries (Brazil and Belgium). The questionnaire, administered online, comprised 23 Likert scale questions and 3 questions eliciting socio-demographic information. Results were analyzed using a linear regression model and compared with previous research using the same energy literacy instrument.

Findings:
The research identified three dimensions of sustainable attitudes: Citizens' role, Scientists' role, and Government's role, explaining 65.5% of respondents' energy-related attitudes. Three dimensions of sustainable behaviours were identified, explaining 64.5% of energy-related behavioural intentions: Consumption of eco-friendly products, financially driven behaviours, and household energy saving. The linear regression model identified Scientists' Role, consumption of eco-friendly products and financially driven behaviour as the key predictors of student energy use. Differences between the two contexts also emerged.

Originality:
Student attitudes and behavioural intentions towards energy are an important element of campus decarbonisation and can act as a catalyst towards a carbon-free society. Although energy literacy research has been undertaken in the US and UK, this research is the first of its kind for Belgium and Brazil and the mode of analysis - using a linear regression model - differs from the earlier work, offering a novel methodological approach.

Keywords: Energy literacy; Decarbonisation; Campus

Article classification: Research paper

Student Energy-Saving in Higher Education: Tackling the Challenge of Decarbonisation

1. Introduction.

1.1. The energy problem

Demographic growth and increasing natural resource exploitation are environmental problems that worsen social issues such as health problems, extreme poverty, and social inequality (Pérez and Frank, 2019). With energy demands rising, and high levels of fossil fuel use, greenhouse gases in the Earth's atmosphere continue to increase, and CO_2 is currently at nearly 412 parts per million (ppm) and still rising. This represents a 47% increase since the beginning of the Industrial Age (Kappelle, 2020). According to the latest IPCC report (2021), 'human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years' (SPM-7). This is a crucial issue for humankind that requires an urgent response.

In Brazil, energy consumption was 16,325 KWh/p in 2019, while in Belgium, consumption was 65,303 KWh/p per person. Compared to 2018, energy consumption increased by 2.22% in Brazil and 4.79% in Belgium (Ritchie, 2021a). Concerning the share of primary energy from renewable sources in 2019 (including hydropower, solar, wind, geothermal, bioenergy, wave, and tidal), Brazil obtains 45.02% of energy from renewable sources, whereas Belgium uses only 6.94% renewables (Ritchie, 2021b).

Energy use in buildings represents 6.5% of direct and 12% of indirect emissions of CO_2 worldwide. To be successful in the transition towards a Post Fossil-Carbon Society, there is a need to reduce this type of energy consumption, as well as to minimize greenhouse gas emissions (EU, 2020; IPCC, 2021). The 'Energy Performance of Buildings Directive' in Europe required all new buildings to be nearly zero-energy by the end of 2020 (EU, 2020). However, additional efforts must be made for existing buildings as only about 1% of the building stock is renovated each year (Magrini *et al.*, 2020). In Brazil, since 2007, the certification body of the Leadership in Energy and Environmental Design (LEED) is the Green Building Council (GBC), which has already received 1,400 enrolments and issued 552 LEED certificates in commerce, industry, and services (UpperSolar, 2020). In both contexts, more work will be needed to meet challenging CO_2 reduction targets.

1.2 Energy and the Sustainable Development Goals.

An increasing number of universities and other Higher Education Institutions (HEIs) are seeking a Sustainable Development agenda for the future (Leal Filho et al., 2019). Historically, HEIs have played a key role in transforming societies, educating decision-makers, leaders, and entrepreneurs (Nejati and Nejati, 2013). Their contribution to Energy Efficiency (EE) goals can be substantial beyond the facilities management realm in promoting individual action in staff and students and undertaking research leading to policy changes. With the introduction of the Sustainable Development Goals (SDGs) (UN, 2015), there is now a clear structure to focus on, and the SDGs have become progressively more established in higher education (HE), frequently referred to in policies and curricula as students increasingly expect a sustainability focus. Engaging with the SDGs can offer benefits to institutions by demonstrating impact, capturing demand for sustainability education, building new partnerships, and accessing new funding streams. Education and research are explicitly recognized in several of the SDGs; thus HEIs, with their broad remit around the creation and dissemination of knowledge and their unique position within society, have a pivotal role to play in their achievement.

Higher Education increasingly needs to equip students with the necessary skills to comprehend and solve wicked problems (Weber *et al.*, 2021). This requires an interdisciplinary approach with new solutions for the economy and society, hence initiatives can often be linked to multiple SDGs. For example, EE projects can obviously have an impact on SDG 7 (sustainable energy) but are also likely to impact SDG 4 (education) and SDG 3 (wellbeing). There is an increasing focus on linking the educational aspects of sustainability with campus developments – encouraging students to undertake projects concerning use of energy in buildings for example. Educational buildings have enormous potential for improvements in energy efficiency. They represent a large volume managed by one single owner (in contrast with the private market). Moreover, they offer a forum to involve various stakeholders (facility managers, visitors, students, and teaching and research staff) with diverse backgrounds to create, support, and marshal evidence for energy conservation. In short, energy efficiency has a key role to play in the move towards using the campus as a living lab (see Franco et al., 2018; Mazutti et al., 2020) – combining student learning with carbon reduction aspirations.

1.3 Aims and Context of the Research

This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in HE. The research was conducted at two universities, PXL University of Applied Sciences in Belgium and the University of Caxias Do Sul in Brazil. It offers novel insights into how students understand energy, their attitudes towards it, and their energy-saving behavioural intentions. The survey has been previously undertaken in the UK, Portugal, and China (Cotton *et al*., 2015; 2016a; 2021). Its use in another European HEI offers the possibility to extend the reach of this survey, and by involving the University of Caxias Do Sul, the first comparison with a Latin American country is possible. This choice is no coincidence as, in 2019, Brazil was the first country in Latin America that is not a member of the International Energy Agency (IEA) to complete the Agency's efficiency indicators questionnaire. Brazil is a priority country in the Agency's Clean Energy Transitions Program (IEA, 2019), and thus offers an exciting new context to explore this issue.

2. Theoretical background and literature review.

2.1 Energy Literacy in Higher Education.

A significant literature on sustainable universities has been emerging over recent years as HEIs recognize the necessity to be seen as leaders in this field, and researchers increasingly turn their attention to their own institutions and sector. Moving beyond the early attempts at campus greening to embed and include student learning in sustainability teaching and research endeavours has proved challenging but rewarding where efforts have been successful. Despite varied national contexts, universities worldwide have made some progress towards the sustainable university model as laid out by Sterling *et al.*, 2013. For example, the recent review by Findler *et al*., (2019) indicates a broad range of research indicating direct and indirect impacts on sustainability arising from the activities of HEIs - though largely in the form of case studies of individual institutions or subjects.

An essential mode of linking campus environmental developments with broader sustainability education has been through energy literacy (DeWaters and Powers, 2011; Cotton *et al*., 2015).

Originating in the US through work by DeWaters and Powers (2011), energy literacy embeds cognitive, affective, and conative elements in a tripartite framework, including:

- knowledge and understanding about energy, its use, and impact on environment and
- attitudes and values, for example, on climate change and the significance of personal actions; and
- intentions/behaviours, for example, to promote energy conservation or to advocate change.

Energy literacy should "… empower people to make appropriate energy-related choices and embrace changes in the way we harness and consume energy." (DeWaters and Powers, 2011, p.1699). In other words, it is aimed at behaviour change – a theoretically contested area with several competing perspectives in the literature.

2.2 Behaviour change.

The literature on behaviour change motivators often refers to the Theory of Reasoned Action (Fishbein and Ajzen, 1975). This theory indicates that behaviour depends on pre-existing attitudes and subjective norms associated with the specific behaviour. It was later developed by Ajzen (1991) and renamed the Theory of Planned Behaviour which included an element of perceived agency. This idea has also been shown to be important in energy-saving behaviours, where students' sense of personal agency in terms of individual behaviour has been seen to be much stronger than their belief that they can influence others (Cotton *et al.*, 2016b). Notably, knowledge plays little role in these theories, and the widespread view has been that knowledge about sustainability issues is insufficient to prompt behaviour change (Blake, 1999; Kollmuss and Agyeman, 2002). Some research into behaviour change towards sustainability has taken a more expansive theoretical framing, using social models of behaviour change (e.g., Stern, 2000; Jackson, 2005). These posit that an individual's ability to change is influenced not only by their personal perspective but also by the surrounding infrastructure (e.g., bicycle lanes or recycling facilities) that supports or inhibits them from changing their behaviour. Social models of behaviour change include Social Practice Theory (Shove, 2010; Hargreaves, 2011) and Sustainable Transition Management (Rotmans *et al.*, 2001; Verbong and Loorbach, 2012). These are 'systems theory' approaches that aspire to changes to society rather than merely to individuals.

The way sustainability issues are framed may also have a significant impact on the likelihood of behavioural change. For example, research by Spence *et al.*, (2014) suggested that framing energy saving in terms of carbon dioxide reduction rather than money-saving could encourage behaviour change. However, other research has identified financial inducements as more effective than verbal encouragement when attempting to encourage 'green' purchasing (Lanzini and Thøgersen, 2014). Research into social marketing approaches to sustainability indicates that an unduly moralizing or fear-inducing message is ineffective in encouraging behaviour change and potentially unethical (French and Gordon, 2019), but that enhanced emotional arousal or engagement can prompt behaviour change (Jacobs and Harms, 2014). Roeser (2012) described emotions as the 'missing link' in encouraging pro-environmental behaviour change, and further evidence of the role of emotion in pro-environmental behaviour was found in experimental work by Morris *et al.*, (2019). A further concept of note is 'behavioural spillover' – which suggests that acting in a pro-environmental way may encourage people to engage in related pro-environmental activities as a protective response to avoid cognitive dissonance (Thøgersen, 1999). Barriers to behaviour change include inertia (habits are difficult to change) and lack of awareness of an issue (Hafner *et al.,* 2019). However, the habit

discontinuity hypothesis (Verplanken and Roy, 2016) suggests that a significant life change may prompt a re-evaluation of long-standing behaviour. Thus, for many students starting university may be an opportunity to make changes toward a more sustainable lifestyle.

2.3 Energy efficiency (EE).

Energy efficiency in HE can take multiple forms. Design of campus buildings, as well as behaviour change of the individuals that use them, are both important elements. In design terms, it is important to take account of the whole life cycle of a building, considering its carbon and material footprint (construction, renovation, retrofitting) (La Fleur et al., 2019). In terms of behaviour change, there is a need to consider technical, social, economic, and educational aspects. Heating, ventilation, and air-conditioning (HVAC) is the primary source of energy consumption in most university buildings, and these are intimately inter-related with the actions of building users. Sanguinetti *et al*. (2017) stressed various energy efficiency goals in buildings: inspiring occupant participation, interpretation of the data, and improving comfort and energy efficiency. Kim *et al.* (2019) detailed the crucial role of facility managers in HE building EE projects. Whitney *et al.* (2020) mentioned the motivation, barriers, and leverage points to achieve an energy reduction for (commercial) buildings. In tandem with EE and energy flexibility, the introduction of renewable energy is an essential tool to realize a carbon-free society (*Blazquez et al.*, (2020).

There are various ways of trying to improve energy consumption in buildings, including the 'trias energetica' method which involves reducing demand, using renewable energy and limiting fossil fuel use as far as possible. An alternative is to utilize a Maintenance Energy Performing Contract (MEPC), which considers not only economic aspects but also incorporates comfort, maintenance, and energy reduction (*Bleyl et al*., 2019). Essential parameters for retrofitting (historic) buildings using an EPC were listed by Tantau (2020) – and they are mostly valid for other buildings. Education buildings have the advantage that they generally have one owner and deal with a large volume of users. Filho *et al.*, (2019) summarised different approaches to EE used by HEIs including pooling buildings to start a deep building renovation, combined with projects with a shorter payback time (Franco *et al.*, 2019 and 2020). Another critical topic is engaging with students, the next generation of leaders, whereby co-creation is both desirable and achievable in terms of building design and use (Franco *et al.,* 2020).

3. Methods and context

3.1 Sample.

The universities involved in this study are PXL University of Applied Sciences (Belgium) and University of Caxias Do Sul (UCS) (Brazil), with 754 students in total participating.

PXL University of Applied Sciences (PXL UAS) is a centre of expertise for innovation, creativity, and entrepreneurship. The institution organizes all activities starting from the quadruple helix model, i.e. the interaction between government, knowledge institutions, industry and society. Because all stakeholders are involved in this quadruple helix model, it is logical that the Energy Efficiency projects are given a more holistic and ecosystemic approach. In this way, such projects can contribute to the well-being of the user of the building (internal climate). Moreover, this building can be part of a healthy environment (external climate). By involving all these stakeholders, it becomes a co-creation process for the HEI in which professors, the business world and students

work together on assignments and realizations. In addition, silos are broken down, there is a shift from linear to circular thinking (Health, 2021). It provides better supported solutions and a gain for the participants; students and business get to know each other better with a view to further professional collaborations, apart from the monetary and environmental gain in the Energy Efficiency project itself.

The University of Caxias Do Sul (UCS) is a centre of innovation, creativity, and entrepreneurship focusing on sustainability. UCS takes part in the ranking of the best universities globally (Times Higher Education) and for the second consecutive year ranked as the most innovative university in Brazil among the community and private universities and positioned as one of the 20 most entrepreneurial companies in the country. Research activities include 28 Masters and Doctorate courses, and the university is also responsible for the training of teachers and professionals with high levels of creativity, resulting in 113 patent registrations at the National Institute of Industrial Property (INPI). The Research and Postgraduate programme brings together professors in 17 Research Centres, 21 Innovation and Development Centres, and 72 Research Groups. The university has 800 laboratories on eight campuses, 92 of which are specific for research related to the provision of services or consultancies. (UCS, 2021). Given the proactive and problem-solving nature of entrepreneurial universities (Segers, 2020), it can be argued that these types of universities have a natural tendency to grapple with societal issues rather than merely engaging in activities that only generate an economic gain. According to Klofsten *et al*. (2019), an entrepreneurial approach will help university leaders to identify and deal with certain leadership challenges and strategic issues. One of the latter is the sustainable development agenda (Fig. 1). Moreover, grappling with societal problems is a two-way street. Apart from the apparent benefits societies garner from university engagement, universities gain advantages too.

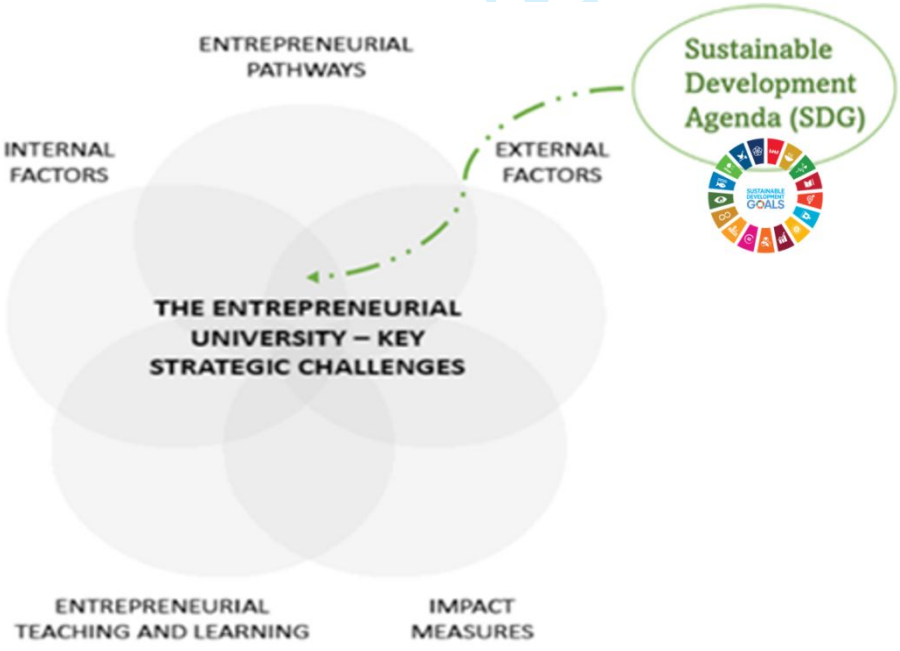

Figure 1 - Key strategic challenges of the entrepreneurial university (Klofsten et al., 2019 - adapted)

Table 1 Gender and age distribution

University	Gender	N (%)	Age	N (%)
Belgium	Male	155 (41.0 %)	20 or under	100 (26.5 %)
	Female	221 (58.5 %)	21-25	117 (31.0 %)
	Missing	1 (0.3%)	26-35	50 (13.2 %)
	Total	378 (100%)	36-47	48 (12.7 %)
			46-55	33 (8.7 %)
			Over 55	29 (7.7%)
			Missing	1 (0.3%)
			Total	378 (100 %)
Brazil	Male	214 (56.9%)	20 or under	105 (27.9 %)
	Female	158 (42.0 %)	21-25	158 (42.0 %)
	Missing	4 (1.1%)	26-35	71 (18.9 %)
	Total	376 (100%)	36-47	12 (3.2 %)
			46-55	2 (0.5 %)
			Over 55	0 (0%)
			Missing	28 (7.4%)
			Total	376 (100 %)

The sample consisted of 754 undergraduate students from Belgium (n = 378) and Brazil (n = 376). The demographics of student respondents are provided in table 1. Most participants in both institutions were under 25 years old, with the Brazilian university being more strongly weighted to younger students. At the Belgian university, most respondents were bachelor students (218 out of 378) but the survey was also carried out among the participants of after-training courses, which explains the slightly higher proportion of older students. The sample is balanced in terms of gender, with 50.7% female respondents, the Belgian sample being slightly female dominated and the Brazilian sample slightly male dominated. Brazilian students are from diverse fields of knowledge: engineering (35.2%) and exact sciences (23.3%), social sciences (29.9%), health sciences (10.6%), and arts and languages (1.0%). For Belgium, the students are also from diverse fields: technologies (31.7%), social sciences, economics, and communication (29.6%), exact sciences (2.8%), health sciences (20.3%), arts and languages (15.6%).

3.2 Survey and analysis

This study builds on the authors' existing work, exploring energy literacy amongst HE students (Cotton *et al.*, 2015; 2016 a & b). We explore participants' attitudes and behavioural intentions with different sustainability approaches using existing scales and validated instruments. The research involved an international team from the UK, Portugal, Brazil, and Belgium. The questionnaire was first translated into Brazilian Portuguese (for Brazilian respondents), Flemish, and English (for Belgian respondents), and then back translated to English to ensure the questions' readability and intelligibility. The original survey instrument contained 40 questions exploring energy knowledge, attitudes, and behavioural intentions and included a mixture of ranking, Likert-type scales, closed and open questions.

A version of the survey developed by Cotton *et al.* (2015) was used in this study, with some modifications to ensure accurate translation. (The survey instrument itself is available here)[1] This survey has been used in previous research in the UK, Portugal, and Belgium (Cotton *et al*., 2015; 2016 a & b; Franco *et al.*, 2018) and in China (Cotton *et al*., 2021). The section on attitudes asked survey respondents to respond statements about their attitudes towards climate change, scientists, and energy efficiency, together with their feelings of agency regarding government and businesses' actions. The section on behaviours asked respondents about behavioural activities, such as paying more for environmental products or turning down heating in rooms. The same 5-point Likert scale was used for the affective and behavioural domains, and examples of individual and social actions were included. Higher scores on these scales generally denote more positive attitudes toward energy-related issues or more effective energy-saving behaviours.

The analyses were performed as mentioned below

(i) descriptive analysis;
(ii) factor analysis to identify the dimensions of attitudes and behaviour;
(iii) regression analysis to identify which dimensions are the most explanatory of energy use;
(iv) analysis of variance, to identify statistically significant differences between countries.

It must be stressed that this survey was undertaken before the pandemic. The survey was open for a long period, but responses tailed off after two months. The survey was made available to students via institutional webpages or direct emails from administrative staff. For ethical reasons, the students were told that the survey was about energy, which may have encouraged more knowledgeable students to respond. The authors are aware of the sample's limitations; however, the overall number of respondents in each institution was high, and respondents were broadly speaking representative of those in the whole institution.

4. Results and Discussion

In this section we present and discuss the descriptive statistics for each dimension of attitude and behavioural intentions, the factor analysis results (for attitudes and behavioural intentions), the tests of differences in means, and the linear regression model explaining students' use of energy. We explore similarities and differences between the two institutions, as well as comparing findings to previous research using the energy literacy survey.

4.1 Sustainable Attitudes Scale.

The internal reliability index of the Sustainable Attitudes scale, measured using Cronbach's alpha, was 0.600, representing a satisfactory internal reliability level (Hair *et al*., 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.613 (Bartlett's Sphericity Test ($p < 0.00$)), a result that points to the factorability of the data. The analysis employed Principal Component Analysis (PCA) with varimax rotation and listwise treatment for missing values. Factor analysis was performed in 4 iterations. The final model showed three dimensions of sustainable attitudes: Citizens' Role, Scientists' Role, and Government's Role (Table 2). The total explained variance was 65.522% with the Citizens' Role dimension explaining 23.560%, the Scientists' Role, 21.332%, and the Government's Role, 20.630%.

[1] https://www.researchgate.net/publication/341179747_Energy_Literacy_Survey_Debby_Cotton

Table 2. Factorial results for attitudes

Dimension	Items	Factor Loading	Mean	Standard deviation
Citizens' Role	A3 – I can influence what the government does about energy problems.	0.871	2.59	1.032
	A4 – I can influence what companies do about energy problems.	0.876	2.60	1.035
Scientists' Role	A6 - Scientists will find ways to solve energy problems.	0.895	3.40	1.019
	A9 - Climate change has been established as a serious problem and immediate action is necessary.	0.790	3.30	1.428
Government's Role	A10 - Climate change is caused by human activities related to using energy	0.758	3.80	0.863
	A8 - The government should have stronger standards on fuel efficiency of cars.	0.754	3.82	0.964
	A7 - More wind farms should be developed to generate electricity, even if they are located in scenic environments.	0.518	3.41	1.080

Note: 1-Strongly disagree, 2- Disagree, 3 Neither agree or disagree, 4-Agree, 5- Strongly agree

The Citizens' Role dimension (M = 2.59; SD = 1.850) includes the variables: (i) "I can influence what the government does about energy problems"; and (ii) "I can influence what companies do about energy problems". This dimension was the one that presented the lowest averages, which suggests that respondents are generally ambivalent or slightly disagree that they can influence government action. This finding has been reported in almost all contexts where the survey has been used. In the UK, students were consistently less confident about their ability to influence others than to engage in personal behaviour change: "the overriding story is one of limited agency, exacerbated by respondents' low incomes and perceived powerlessness" (Cotton *et al.*, 2016a, p. 894). In Portugal, students expressed somewhat stronger agency than those in the UK (Cotton *et al.*, 2016b), and in China, this was one of the most vital elements of the student response, perhaps reflecting a more collectivist culture (Cotton *et al.*, 2021). Similar results were found in Mulder *et al.* (2010), which analysed the learning outcomes of 500 students from five European Technological Universities concerning the sustainable development and the pedagogical approach adopted. The results demonstrate that students initially perceived sustainability mainly related to technological aspects, believing that technology can offer solutions to environmental problems and perceived little relevance of sustainability's social and behavioural aspects.

For environmental problems to be minimized and for an improvement in environmental quality to occur, changing individuals and society's behaviour is fundamental to improving environmental and life quality - this is an issue that requires an educational process and environmental awareness (Lozano *et al.*, 2019). The Scientists' Role dimension (M = 3.34; SD = 1.059) includes the variables: (i) "Scientists will find ways to solve energy problems"; and (ii) "Climate change has been established as a serious problem, and immediate action is necessary". This dimension had an average higher than 3.0, indicating that respondents believe in climate change and are confident about scientists' role in solving the climate crisis. All groups were considerably more likely to think that scientists will find solutions than that governments will act, which echoes the UK and Portuguese findings (Cotton *et al.*, 2016a and b), but the reverse was found in the Chinese sample (Cotton *et al.*, 2021). These

results are in line with the study by Nejati and Nejati (2013), which also evaluated students' perception of the university's performance in creating partnerships with the government, non-governmental organizations, and the industry working towards sustainability. Leal Filho and colleagues (2015) showed that the government's role must go beyond financial support for universities, in encouraging universities to make education more flexible for sustainability and identifying opportunities in the green economy.

The third dimension, Government's Role (M = 3.67; SD = 1.991) includes the variables: (i) "Climate change is caused by human activities related to using energy"; (ii) "The government should have stronger standards on the fuel efficiency of cars."; and (iii) "More wind farms should be developed to generate electricity, even if they are in scenic environments". This dimension was the one that presented the highest averages, which suggests that respondents agree with the statements. Again, this echoes findings in the UK and Portugal (Cotton *et al*., 2016b) but contrasts with China's findings (Cotton *et al.*, 2021), perhaps reflecting the more significant cultural similarity with the UK and Portuguese contexts of these groups of students.

4.2 Sustainable Behaviours Scale.

The internal reliability index of the Sustainable Behaviours scale, measured using Cronbach's alpha, was 0.620, representing a satisfactory internal reliability level (Hair *et al.*, 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.644 (Bartlett's Sphericity Test ($p < 0.00$)), a result that points to the factorability of the data. The factor analysis employed the Principal Component Analysis (PCA) with varimax rotation and listwise treatment for missing values. Factor analysis was performed in 5 iterations. The final model showed three dimensions of sustainable behaviours (Table 3). A total explained variance was 64.543%; the Consumption of eco-friendly products explains 23.395%, Financially-driven behaviour 20.871%, and Household energy-saving 20.278%.

Table 3. Factorial results for behaviours

Dimension	Items	Factor Loading	Mean	Standard deviation
Consumption of eco-friendly products	B17 - Buy things that are likely to involve less energy or resource use.	0.823	2.35	0,822
	B18 - Pay a bit more for environmentally friendly products.	0.860	2.41	0.819
Financially driven behaviours	B19 - Avoid charging mobile phones overnight.	0.798	2.31	1.084
	B20 - Turn off the stand-by button of the TV set or switch appliances off at the plug.	0.766	2.60	1.117
Household energy saving	B13 - Turn off lights when they are not in use.	0.737	3.63	0.561
	B14 - Turn down the heat or air conditioning.	0.727	3.21	0.875
	B15 - Try to save water.	0.589	3.02	0.785

1-never, 2-infrequently, 3-frequently, 4-always

The ordering of these behavioural items from most to least popular is remarkably similar across student populations in a wide range of contexts in which the survey has been used. Turning off lights is almost invariably the most popular energy-saving activity by students, suggesting that this behaviour is almost ubiquitous and automatic. Behaviours that involve financial outlay are generally less popular with students, reflecting, at least in part, their limited financial position. Avoiding charging phones overnight also often rates as less popular and is somewhat controversial, particularly as phone technology improves to reduce the risk of power usage when fully charged. This pattern of responses can be seen in the Portuguese and UK respondents (Cotton *et al.*, 2016b) but not in the Chinese sample (Cotton *et al.*, 2021).

4.3 Linear regression analysis.

The relationship between the dimensions of attitudes and behaviours and the variable "When it comes to energy use, how would you describe yourself" was tested by linear regression, using the stepwise method (Table 4). The energy use variable (M= 2.77; SD = 0.891) was assessed on a scale of 1 to 5, with 1 for respondents who consider themselves low energy users and 5 for respondents who consider themselves high energy users. The results of the linear regression show that three dimensions in the model are significant for the use of energy and represent 20.3% (R2 = 0.203, p <0.05) of the overall use assessment: Scientists' Role, Consumption of Eco-friendly products, and Financially-driven behaviour. The Durbin-Watson test was employed to detect the presence of autocorrelation (dependence) in the residuals of a regression analysis (Hair *et al*., 2003). The model's test value (1.872) indicates that the residuals are independent (with a 95% confidence level).

In other words, the overall assessment of the use of energy depends significantly on the performance of these dimensions (Table 4). The model equation can be written as follows:

USE OF ENERGY = 0.210 + 0.381 * Scientists' Role – 0.150 * Consumption of Eco-friendly products – 0.139 * Financially-driven behaviour *{equation 1}*

Table 4. Linear regression model

Model	R	R Square	Adjusted R Square	St. Error of the Estimate	Durbin-Watson
1	0.391[a]	0.153	0.152	0.820	
2	0.435[b]	0.189	0.187	0.803	
3	0.454[c]	0.206	0.203	0.795	1.872

a. Predictors: (Constant), Scientists' Role

b. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products

c. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products, Financially-driven behaviour

The most important dimension in the assessment of energy use is "Scientists' role" (beta = 0.381; sig. 0.0000), which means that energy use increases with the belief that scientists will solve the energy problem and decreases as people consume more eco-friendly products and adopt more economy driven behaviours.

Table 5. Linear regression coefficients

Final Model	Unstandardized		Standardized	t	p
	B	Std. Error	Beta		
(Constant)	2.967	0.210		13.937	0.000
Scientists' Role	0.318	0.028	0.381	11.155	0.000
Consume of Eco-friendly products	-0.186	0.044	-0.150	-4.235	0.000
Economy driven behaviour	-0.234	0.059	-0.139	-3.953	0.000

4.4 Differences between Brazilian and Belgian respondents.

All dimensions showed significant differences for respondents from Brazil and Belgium. Only the Scientists' Role did not pass the homogeneity of variance test (Levene's test), but as the samples from Brazil (n = 376) and Belgium (n = 378) have sample' size variation of less than 10%, the homoscedasticity test does not affect the analysis of variance (Pestana and Gageiro, 2005). The ANOVA test allows us to conclude that there are significant differences between respondents from both countries for all dimensions of attitudes and behaviours.

Across all three attitudinal dimensions (Scientists 'role, Citizens' role and Government's role), Brazilian students scored more highly. Brazilian students expressed a strong faith in Science (F=529.938; sig=0.000), indicating that Brazilian students have a strong belief that scientists will find ways to solve energy problems and that climate change demands immediate action. Brazilian students also felt more strongly about the Citizens' role (F=197.333; sig=0.000), expressing a stronger sense of agency and a stronger agency to influence the government and companies' actions. And finally, they expressed stronger support for the government taking a role in energy issues (F=23.444; sig=0.000) – for example by bringing in stronger standards on fuel efficiency in cars. In terms of the behavioural dimensions, Brazilian's students were more financially driven (F=38.351; sig=0.000) overall. Belgian students showed greater propensity for consumption of eco-friendly products (F=7.745; sig=0.000) and household energy saving (F=273.939; sig=0.000). A possible explanation might be linked to the fact that the average age of participants was higher at the Belgian institution and that they may have lower expectations of third parties (75.6% of the Brazilian respondents were under 25 years old, while 57.6% of the Belgian respondents are in that age group). Moreover, the typical Belgian governance structures (federal versus regional level) will also not promote "belief in government". The third layer from the EU may increase the complexity still further and thus reduce the trust in the government as a third partner for the Belgian participants.

Table 6. Institutional differences

Dimension	Belgium		Brazil	
	Mean	SD	Mean	SD
Attitudinal dimensions				
Scientists' role	2.667	0.939	4.035	0.653
Citizens' role	2.178	0.790	3.026	0.852
Government's role	3.560	0.646	3.792	0.661
Behavioural dimensions				
Consumption of eco-friendly products	2.459	0.697	2.313	0.735
Financially driven behaviour	3.173	0.508	3.407	0.518
Household energy saving	2.922	0.731	1.984	0.817

Despite the scepticism illustrated by their attitudinal positions, the Belgian respondents scored quite highly on the behavioural dimensions. It is known that an individual's behaviour is not always consistent with their attitudes. Bael (2009) has previously shown that people exhibit varied behaviours in different contexts and under the influence of different external and internal factors and actions may or may not be consistent with their underlying attitudes. Sometimes an individual's behaviour is influenced less by their underlying attitudes than by the prevailing social norms. This could be an explanation for the Belgian behavioural dimensions being mostly higher than the Brazilian ones. There are significant current initiatives within the University (PXL) to include sustainability in their policies which may have had a positive influence on their students' behaviour in comparison with Brazilian students.

In addition, the World Values Survey (Halpern, 2005; Inglehart, 2014) indicates that, historically, Brazil has been among the nations with a low social capital level and a downward trend. Social capital can be understood as the systems of participation and reciprocity that involve community relations (Putnam, 1993). When social capital is less present, there is a tendency towards opportunism and selfish attitudes and behaviours since it implies that individuals can engage in the common good (Coleman, 1990; Inglehart, 2014). On the other hand, in Belgium, social capital levels are higher and tending to increase, showing a more communitarian spirit in attitudes and behaviours. However, further research would be needed to confirm this hypothesis. There are some interesting opportunities to explore the impact of personal, situational and behavioural variables on the relationship between attitudes and behaviour (Roberts *et al*., 2017). Analysing the cultural dimensions of both countries following the framework provided by Hofstede (2011) might also be informative in providing a better understanding of the differences between the countries and the ways in which they might influence individual behaviour. An analysis of the psychographics (e.g., lifestyles and values) would enrich future analysis.

In Brazil, not so many HEI (9) are active on the SDGs or agenda 2030, despite addressing sustainability practices (Pontelli et al., 2019), demonstrating a gap to be filled regarding sustainable development especially in public institutions. This collaboration and exchange of information between the EU countries and more specific with the Belgian PXL UAS can make a priority of Energy Efficiency for the University of Caxias Do Sul.

PXL UAS is the first SDG pioneer in Belgium and rather an atypic illustration. As the institution organizes all activities starting from the quadruple helix model, i.e. interaction between government, knowledge institutes, industry, and society. The quadruple helix approach illustrates the interaction with all stakeholders and the interdisciplinarity shows to all of them that Energy Efficiency projects incorporate economic benefits, as well as education, wellbeing, and community engagement, which improves the actions and interpretations of these stakeholders (including the students).

5. Conclusions

This research involved deploying a widely used, rigorously tested energy literacy survey in two novel contexts, and using a new analytical approach. Three elements of sustainable attitudes and three elements of sustainable behaviours have been identified, and a linear regression analysis used to develop an equation linking certain attitudes and behavioural dimensions to overall energy usage. This enhanced theoretical model of individual energy use offers an additional tool to explore energy literacy in future research and suggests that overall energy use is positively related to consumption of eco-friendly products and financially driven behaviour but negatively related to a strong belief in science, suggesting a possible over-optimism about the role of scientists in solving energy problems. This new insight emphasises the need for care to be taken in educational contexts to ensure that students understand that there is a role for individual action as well as scientific advance and government regulation in combating climate change. Differences between the two contexts also emerged, with Brazilian students being generally more optimistic about the role of scientists, citizens, and the government than those in Belgium. Perhaps reflecting students' different economic circumstances in the two countries, those in Brazil were more financially motivated, and the Belgian students showed a greater propensity for consumption of eco-friendly products and household energy saving. Notice that previous studies have reported that energy consumption was higher in Brazil, thus this could be a way Belgium students ameliorate the problem.

It is not clear that in either context, the attitudes and behaviours of respondents are sufficient to drive the level of change needed to avert the climate crisis. It is also necessary to take into account the influence of the surrounding infrastructure, and the impact of the theory of change in society. Echoing previous research in the UK and Portuguese context, this study notes the limited sense of agency felt by students both in Belgium and Brazil regarding influencing the actions of government or businesses. These are sobering findings, given the clear need for strong political action globally. There is also evidence that, like most of the students surveyed worldwide, the behaviours which were most undertaken were not those that save the most energy! Students in Belgium and Brazil, as with those in the UK and Portugal, were more likely to see turning off lights and other similar activities as playing a pivotal role, despite their limited impact on energy use overall. Findings differed significantly from the Chinese context, leaving this as an outlier where students had hugely different attitudes and behaviours towards energy saving – with the Chinese respondents indicating less positive attitudes towards energy saving and a lower likelihood of making individual behaviour changes, but having a greater trust in government to act (Cotton et al. 2021). Further research on cultural context, and the implications for energy saving and sustainability education would be extremely valuable.

In terms of the behaviour change theories discussed earlier, our research illustrates the importance of attitudinal variables in influencing behaviour change (as per the theory of reasoned action), but also considers perceived agency (added into the theory of planned behaviour) as a mediating variable. This issue is complex and in a sense our research adds weight to the social theories of behaviour change in expanding this notion of agency beyond the individual and their own lifestyle to include their perception of being able to influence other bodies (government and companies). Looking more deeply still, we can observe a tension between the positive impact on behaviour change of feeling that one can influence others' behaviours (such as government and companies) and thus promoting forms of political and social action, and the negative impact of feeling that – as in this instance – scientists will be able to solve all the energy problems. There's a delicate balance to be found here between encouraging a trust in science – but without allowing people to externalise the responsibility for climate change mitigation onto another group (scientists). The precise ways and extent to which local subjective norms and available infrastructure in each setting impact on actual energy-saving behaviours would be worthy of further research.

This paper contributes to a broader debate on strategies for implementation of Education for Sustainable Development (ESD) and education for sustainability (EfS) by mapping arguments on competencies for SD and sustainability with a particular focus on higher education institutions. Our findings suggest that: (i) universities should focus on individual behavioural changes alongside teaching sustainability science (to reduce the risk that students rely on scientists to solve energy problems); (ii) governments should encourage public policies to raise awareness of the role of citizens in the sustainable use of energy; and (iii) universities should identify key elements for the construction of north-south cooperation proposals, such as capacity building programs for the dissemination of best sustainable practices. By identifying factors influencing students' perceptions of sustainability, and their energy saving activities, this study provides pertinent evidence for social researchers and university managers on ways in which the sustainable university ideal might be realised.

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Reviewers' comments and authors' responses:

Comment	Response
Referee 1: Minor revisions Overall, the paper is an engaging and useful addition to the body of work in the area. The following minor corrections (1 & 2) should be made before the publication goes ahead:	Thank you for your help in improving this paper for publication.
1) Regarding Table 4, it is not clear why the superscript reference, d, appears at the bottom of this table (d Dependent Variable: A12 - When it comes to energy use, how would you describe yourself). The 'd' superscript itself doesn't appear anywhere in the table. The same superscript reference appears as 'a' at the bottom of Table 5 and also doesn't appear to be used in the table.	Thanks for this comment. We've included the subscript references on Table 4 and 5.
2) Page 14, second paragraph, lines 30, 31, 32. The statement 'Findings differed significantly from the Chinese context, leaving this as an outlier where students had hugely different attitudes and behaviours towards energy saving.' is a little vague considering that the work is intended to build on previous studies. To help the reader, it would be useful to again provide a citation supporting this statement and also add one or two sentences that explain briefly what the most significant difference(s) is(are).	We included the reference Cotton et al (2021), and some additional information about the comparison made as below: Findings differed significantly from the Chinese context, leaving this as an outlier where students had hugely different attitudes and behaviours towards energy saving – with the Chinese respondents indicating less positive attitudes towards energy saving and a lower likelihood of making individual behaviour changes, but having a greater trust in government to act (Cotton et al. 2021).
(The rest of the comments are all very positive, so in the interests of space, I have left them out of this table).	Thanks for the opportunity to revise our manuscript!
Referee 2: Minor revisions 1) Would like to see more in the way of connections between the theoretical framework and the conclusions, as they really do seem a bit distant, and the findings are very generic. I think there is something really interesting in the work, but it is not coming through. perhaps revisit the foundational theories and see how the results of the survey and findings can help support or disprove any of the underlying concepts.	Thank you for your help in improving this paper for publication. We have substantially revised the final section of the paper to incorporate consideration of behaviour change theories and in particular tensions within the notion of agency – and the extent to which our findings offer support for the social models of behaviour change.
2) The paper has new information from the regions of the surveys, and contributes to the existing information compiled from China and elsewhere. it is not clear if the information is significant - for significance, I would ask whether the conclusions are influential in terms of how we think about sustainability attitudes and behavioral intentions. In order for this paper to meet that standard, I suggest the authors might examine the results more deeply to see if there are any insights that could be universally relevant (as opposed to relevant in Brazil and Belgium only).	We have substantially revised the conclusions section to strengthen the theoretical insights and emphasize those elements which we feel are more widely relevant. In particular, we have focused on returning to the theories of behaviour change (as described above) to offer some more universally relevant insights and suggestions for further research.
3) Yes, this paper is very well researched and the background lit review is comprehensive and well-focused on the specific areas of examination.	Thank you
4) The three main findings suggest that behaviors and education should go hand in, governments should do more, and universities have a greater role in	We have substantially revised the description of the two HEI and the role

promoting global north/south cooperation. These findings are quite generic, and not sure if anything in the paper actually supports these findings. The interesting aspects of the research were the differences between the two sample locations, and I would expect the conclusions to highlight some interesting analyses of why the regions are different, what is more universal in terms of attitudes and behaviors, and so on. The researchers might even look into whether the results from the two schools are unique characteristic of the schools, or could be more broadly generalized as a representing the attitudes of the region. These areas of focus would have been quite interesting.	and the approach the sustainable aspects paly in their civic partnerships. In addition, the atypical position of the PXL UAS (the first SDG Pioneer in Belgium) and the catalytic effect for the Brazilian partner has been described.
5) The writing is clear and concise. A bit excessively school-promotional in the descriptions of the universities(section 3.1) but generally very readable and interesting.	We have reviewed the paper in order to ensure clarity of writing and expression throughout.
Deputy Editor: This manuscript is well presented and is of the required standard. It is original and presents its findings well. *The theoretical framework links to the actual studied should be deepened and a more critical voice taken throughout.* There are only some other points that need to be amended in order for it to be publishable. These are found within the reviewers comments. Kindly go through and amend as required and also present a list of changed made in the form of a rebuttal letter.	We have revised the entire paper, making small changes to throughout to ensure clarity and readability (they all are in blue). In relation to the sentence in italics, we have substantially revised the conclusions and added an entirely new paragraph which explicitly links the findings back to the behaviour change theories (additional references are mentioned in red).

Student Energy-Saving in Higher Education
Tackling the Challenge of Decarbonisation

Structured Abstract

Purpose:
This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in higher education settings.

Methodology:
We used a validated energy literacy survey to assess undergraduate students' attitudes and behavioural intentions towards energy-saving in two countries (Brazil and Belgium). The questionnaire, administered online, comprised 23 Likert scale questions and 3 questions eliciting socio-demographic information. Results were analyzed using a linear regression model and compared with previous research using the same energy literacy instrument.

Findings:
The research identified three dimensions of sustainable attitudes: Citizens' role, Scientists' role, and Government's role, explaining 65.5% of respondents' energy-related attitudes. Three dimensions of sustainable behaviours were identified, explaining 64.5% of energy-related behavioural intentions: Consumption of eco-friendly products, financially driven behaviours, and household energy saving. The linear regression model identified Scientists' Role, consumption of eco-friendly products and financially driven behaviour as the key predictors of student energy use. Differences between the two contexts also emerged.

Originality:
Student attitudes and behavioural intentions towards energy are an important element of campus decarbonisation and can act as a catalyst towards a carbon-free society. Although energy literacy research has been undertaken in the US and UK, this research is the first of its kind for Belgium and Brazil and the mode of analysis - using a linear regression model - differs from the earlier work, offering a novel methodological approach.

Keywords: Energy literacy; Decarbonisation; Campus

Article classification: Research paper

Student Energy-Saving in Higher Education: Tackling the Challenge of Decarbonisation

1. Introduction.

1.1. The energy problem

Demographic growth and natural resource exploitation at increasing rates are environmental problems that worsen social issues such as health problems, extreme poverty, and social inequality (Pérez and Frank, 2019). With energy demands rising, and high levels of fossil fuel use, greenhouse gases in the Earth's atmosphere continue to increase, and CO_2 is currently at nearly 412 parts per million (ppm) and still rising. This represents a 47% increase since the beginning of the Industrial Age (World Meteorological Organization, 2019). According to the latest IPCC report (2021), 'human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years' (SPM-7). This is a crucial issue for humankind that requires an urgent response.

In Brazil, energy consumption was 16,325 KWh/p in 2019, while in Belgium, consumption was 65,303 KWh/p per person. Compared to 2018, energy consumption increased by 2.22% in Brazil and 4.79% in Belgium (Ritchie, 2021). Concerning the share of primary energy from renewable sources in 2019 (including hydropower, solar, wind, geothermal, bioenergy, wave, and tidal), Brazil obtains 45.02% of energy from renewable sources, whereas Belgium uses only 6.94% renewables (Ritchie, 2021).

Energy use in buildings represents 6.5% of direct and 12% of indirect emissions of CO_2 worldwide. Thus, to be successful in the transition towards a Post Fossil-Carbon Society, there is a need to reduce this type of energy consumption, as well as to minimize greenhouse gas emissions (EC, 2020; IPCC, 2021). The 'Energy Performance of Buildings Directive' in Europe required all new buildings to be nearly zero-energy by the end of 2020. However, additional efforts must be made for existing buildings as only about 1% of the building stock is renovated each year (Magrini *et al.*, 2020). In Brazil, since 2007, the certification body of the Leadership in Energy and Environmental Design (LEED) is the Green Building Council (GBC), which has already received 1,400 enrolments and issued 552 LEED certificates in commerce, industry, and services (UpperSolar, 2020). In both contexts, more work will be needed to meet challenging CO_2 reduction targets.

1.2 Energy and the Sustainable Development Goals.

An increasing number of universities and other Higher Education Institutions (HEIs) are seeking a Sustainable Development agenda for the future (Leal Filho et al., 2019). Historically, HEIs have played a key role in transforming societies, educating decision-makers, leaders and entrepreneurs (Nejati and Nejati, 2013). Their contribution to Energy Efficiency (EE) goals can be substantial beyond the facilities management realm in promoting individual action in staff and students, and undertaking research leading to policy changes. With the introduction of the Sustainable Development Goals (SDGs) (UN, 2015), there is now a clear structure for HEIs to focus on, and the SDGs have become progressively more established in higher education (HE), frequently referred to in sustainability policies and curricula as students increasingly expect a sustainability focus. Engaging with the SDGs can offer benefits to institutions by demonstrating impact, capturing demand for sustainability education, building new partnerships and accessing new funding streams. Education and research are explicitly recognized in several of the SDGs; thus HEIs, with their broad remit around the creation and dissemination of knowledge and their unique position within society, have a pivotal role to play in their achievement.

Higher Education increasingly needs to equip students with the necessary skills to comprehend and solve wicked problems (Weber *et al.*, 2021). This requires an interdisciplinary approach with new solutions for the economy and society, hence initiatives can often be linked to multiple SDGs. For example, EE projects can obviously have an impact on SDG 7 (sustainable energy), but are also likely to impact SDG 4 (education) and SDG 3 (wellbeing). There is an increasing focus on linking the educational aspects of sustainability with campus developments – encouraging students to undertake projects concerning use of energy in buildings for example. Educational buildings have enormous potential for improvements in energy efficiency. They represent a large volume managed by one single owner (in contrast with the private market). Moreover, they offer a forum to involve various stakeholders (facility managers, visitors, students, and teaching and research staff) with diverse backgrounds to create, support, and marshal evidence for energy conservation. In short, energy efficiency has a key role to play in the move towards using the campus as a living lab (see Franco et al., 2018; Mazutti et al., 2020) – combining student learning with carbon reduction aspirations.

1.3 Aims and Context of the Research

This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in HE. The research was conducted at two universities, PXL University of Applied Sciences in Belgium and the University of Caxias Do Sul in Brazil. It offers novel insights into how students understand energy, their attitudes towards it, and their energy-saving behavioural intentions. The survey has been previously undertaken in the UK, Portugal, and China (Cotton *et al*., 2015; 2016a; 2021). Its use in another European HEI offers the possibility to extend the reach of this survey, and by involving the University of Caxias Do Sul, the first comparison with a Latin American country is possible. This choice is no coincidence as, in 2019, Brazil was the first country in Latin America that is not a member of the International Energy Agency (IEA) to complete the Agency's efficiency indicators questionnaire. Brazil is a priority country in the Agency's Clean Energy Transitions Program (IEA, 2019), and thus offers and exciting new context to explore this issue.

2. Theoretical background and literature review.

2.1 Energy Literacy in Higher Education.

A significant literature on sustainable universities has been emerging over recent years as HEIs recognize the necessity to be seen as leaders in this field, and researchers increasingly turn their attention to their own institutions and sector. Moving beyond the early attempts at campus greening to embed and include student learning in sustainability teaching and research endeavours has proved challenging but rewarding where efforts have been successful. Despite varied national contexts, universities worldwide have made some progress towards a sustainable university model as laid out by Sterling *et al.*, 2013. For example, the recent review by Findler *et al*., (2019) indicates a broad range of research indicating direct and indirect impacts on sustainability arising from the activities of HEIs - though largely in the form of case studies of individual institutions or subjects.

An essential mode of linking campus environmental developments with broader sustainability education has been through energy literacy (DeWaters and Powers, 2011; Cotton *et al*., 2015). Originating in the US through work by DeWaters and Powers (2011), energy literacy embeds cognitive, affective, and conative elements in a tripartite framework, including:

- knowledge and understanding about energy, its use, and impact on environment and
- attitudes and values, for example, on climate change and the significance of personal actions; and
- intentions/behaviours, for example, to promote energy conservation or to advocate change.

Energy literacy should "… empower people to make appropriate energy-related choices and embrace changes in the way we harness and consume energy." (DeWaters and Powers, 2011, p.1699). In other words, it is aimed at behaviour change – a theoretically contested area with several competing perspectives in the literature.

2.2 Behaviour change.

The literature on behaviour change motivators often refers to the Theory of Reasoned Action (Fishbein and Ajzen, 1975). This theory indicates that behaviour depends on pre-existing attitudes and subjective norms associated with the specific behaviour. It was later developed by Ajzen (1991) and renamed the Theory of Planned Behaviour which included an element of perceived agency. This idea has also been shown to be important in energy-saving behaviours, where students' sense of personal agency in terms of individual behaviour has been seen to be much stronger than their belief that they can influence others (Cotton *et al.*, 2016b). Notably, knowledge plays little role in these theories, and the widespread view has been that knowledge about sustainability issues is insufficient to prompt behaviour change (Blake, 1999; Kollmuss and Agyeman, 2002). Some research into behaviour change towards sustainability has taken a more expansive theoretical framing, using social models of behaviour change (e.g., Stern, 2000; Jackson, 2005). These posit that an individual's ability to change is influenced not only by their personal perspective but also by the surrounding infrastructure (e.g., bicycle lanes or recycling facilities) that supports or inhibits them from changing their behaviour. Social models of behaviour change include Social Practice Theory (Shove, 2010; Hargreaves, 2011) and Sustainable Transition Management (Rotmans *et al.*, 2001; Verbong and Loorbach, 2012). These are 'systems theory' approaches that aspire to changes to society rather than merely to individuals.

The way sustainability issues are framed may also have a significant impact on the likelihood of behavioural change. For example, research by Spence *et al.*, (2014) suggested that framing energy saving in terms of carbon dioxide reduction rather than money-saving could encourage behaviour change. However, other research has identified financial inducements as more effective than verbal encouragement when attempting to encourage 'green' purchasing (Lanzini and Thøgersen, 2014). Research into social marketing approaches to sustainability indicates that an unduly moralizing or fear-inducing message is ineffective in encouraging behaviour change and potentially unethical (French and Gordon, 2019), but that enhanced emotional arousal or engagement can prompt behaviour change (Jacobs and Harms, 2014). Roeser (2012) described emotions as the 'missing link' in encouraging pro-environmental behaviour change, and further evidence of the role of emotion in pro-environmental behaviour was found in experimental work by Morris *et al.*, (2019). A further concept of note is 'behavioural spillover' – which suggests that acting in a pro-environmental way may encourage people to engage in related pro-environmental activities as a protective response to avoid cognitive dissonance (Thøgersen, 1999). Barriers to behaviour change include inertia (habits are difficult to change) and lack of awareness of an issue (Hafner *et al.,* 2019). However, the habit discontinuity hypothesis (Verplanken and Roy, 2016) suggests that a significant life change may prompt a re-evaluation of long-standing behaviour. Thus, for many students starting university may be an opportunity to make changes toward a more sustainable lifestyle.

2.3 Energy efficiency (EE).

Energy efficiency in HE can take multiple forms. Design of campus buildings, as well as behaviour change of the individuals that use them, are both important elements. In design terms, it is important to take account of the whole life cycle of a building, considering its carbon and material footprint (construction, renovation, retrofitting) (La Fleur et al., 2019). In terms of behaviour of change, there is a need to consider technical, social, economic and educational aspects. Heating, ventilation, and air-conditioning (HVAC) is the primary source of energy consumption in most university buildings, and these are intimately inter-related with the actions of building users. Sanguinetti *et al*. (2017) stressed various energy efficiency goals in buildings: inspiring occupant participation, interpretation of the data, and improving comfort and energy efficiency. Kim *et al.* (2019) detailed the crucial role of facility managers in HE building EE projects. Whitney *et al.* (2020) mentioned the motivation, barriers, and leverage points to achieve an energy reduction for (commercial) buildings. In tandem with EE and energy flexibility, the introduction of renewable energy is an essential tool to realize a carbon-free society (*Blazquez et al.*, (2020).

There are various ways of trying to improve energy consumption in buildings, including the 'trias energetica' method which involves reducing demand, using renewable energy and limiting fossil fuel use as far as possible. An alternative is to utilize a Maintenance Energy Performing Contract (MEPC), which considers not only economic aspects but also incorporates comfort, maintenance, and energy reduction (*Bleyl et al*., 2019). Essential parameters for retrofitting (historic) buildings using an EPC were listed by Tantau (2020) – and they are mostly valid for other buildings. Education buildings have the advantage that they generally have one owner and deal with a large volume of users. Filho *et al.*, (2019) summarised different approaches to EE used by HEIs including pooling buildings to start a deep building renovation, combined with projects with a shorter payback time (Franco *et al.*, 2019 and 2020). Another critical topic is engaging with students, the next generation of leaders, whereby co-creation is both desirable and achievable in terms of building design and use (Franco *et al.,* 2020).

3. Methods and context

3.1 Sample.

The universities involved in this study are PXL University of Applied Sciences (Belgium) and University of Caxias Do Sul (UCS) (Brazil), with 754 students in total participating. The PXL University of Applied Sciences is a centre of expertise for innovation, creativity, and entrepreneurship. The institution organizes all activities starting from the quadruple helix model (interaction between government, knowledge institutes, industry, and society). Because all stakeholders (government, business, knowledge institutions and society) are involved in the quadruple helix model, it is logical that the Energy Efficiency projects are given a more holistic and ecosystemic approach. In this way, such projects contribute to the well-being of the user of the building (internal climate). Moreover, this building can be part of a healthy environment (external climate). By involving all these stakeholders, it becomes a co-creation process for the HEI in which professors, the business world and students work together on assignments and realizations. In addition, silos are broken down, and there is a shift from linear to circular thinking (Health (2021). It provides better (more supported) solutions and a gain for the participants; students and business get to know each other

better with a view to further professional collaborations, apart from the monetary and environmental gain in the EE project itself.

The University of Caxias Do Sul (UCS) is a centre of innovation, creativity, and entrepreneurship focusing on sustainability. UCS takes part in the ranking of the best universities globally (Times Higher Education) and for the second consecutive year ranked as the most innovative university in Brazil among the community and private universities and positioned as one of the 20 most entrepreneurial companies in the country. Research activities include 28 Masters and Doctorate courses, and the university is also responsible for the training of teachers and professionals with high levels of creativity, resulting in 113 patent registrations at the National Institute of Industrial Property (INPI). The Research and Postgraduate programme brings together professors in 17 Research Centres, 21 Innovation and Development Centres, and 72 Research Groups. The university has 800 laboratories on eight campuses, 92 of which are specific for research related to the provision of services or consultancies. (UCS, 2021).

Table 1 Gender and age distribution

University	Gender	N (%)	Age	N (%)
Belgium	Male	155 (41.0 %)	20 or under	100 (26.5 %)
	Female	221 (58.5 %)	21-25	117 (31.0 %)
	Missing	1 (0.3%)	26-35	50 (13.2 %)
	Total	378 (100%)	36-47	48 (12.7 %)
			46-55	33 (8.7 %)
			Over 55	29 (7.7%)
			Missing	1 (0.3%)
			Total	378 (100 %)
Brazil	Male	214 (56.9%)	20 or under	105 (27.9 %)
	Female	158 (42.0 %)	21-25	158 (42.0 %)
	Missing	4 (1.1%)	26-35	71 (18.9 %)
	Total	376 (100%)	36-47	12 (3.2 %)
			46-55	2 (0.5 %)
			Over 55	0 (0%)
			Missing	28 (7.4%)
			Total	376 (100 %)

The sample consisted of 754 undergraduate students from Belgium (n = 378) and Brazil (n = 376). The demographics of student respondents are provided in table 1. Most participants in both institutions were under 25 years old, with the Brazilian university being more strongly weighted to younger students. At the Belgian university, most respondents were bachelor students (218 out of 378) but the survey was also carried out among the participants of after-training courses, which explains the slightly higher proportion of older students. The sample is balanced in terms of gender, with 50.7% female respondents, the Belgian sample being slightly female dominated and the Brazilian sample slightly male dominated. Brazilian students are from diverse fields of knowledge: engineering (35.2%) and exact sciences (23.3%), social sciences (29.9%), health sciences (10.6%), and arts and languages (1.0%). For Belgium, the students are also from diverse fields: technologies

(31.7%), social sciences, economics, and communication (29.6%), exact sciences (2.8%), health sciences (20.3%), arts and languages (15.6%).

3.2 Survey and analysis

This study builds on the authors' existing work, exploring energy literacy amongst HE students (Cotton *et al.*, 2015; 2016 a & b). We explore participants' attitudes and behavioural intentions with different sustainability approaches using existing scales and validated instruments. The research involved an international team from the UK, Portugal, Brazil, and Belgium. The questionnaire was first translated into Brazilian Portuguese (for Brazilian respondents), Flemish, and English (for Belgian respondents), and then back translated to English to ensure the questions' readability and intelligibility. The original survey instrument contained 40 questions exploring energy knowledge, attitudes, and behavioural intentions and included a mixture of ranking, Likert-type scales, closed and open questions.

A version of the survey developed by Cotton *et al.* (2015) was used in this study, with some modifications to ensure accurate translation. (The survey instrument itself is available here)[1] This survey has been used in previous research in the UK, Portugal, and Belgium (Cotton *et al*., 2015; 2016 a & b; Franco *et al.*, 2018) and in China (Cotton *et al*., 2021). The section on attitudes asked survey respondents to respond statements about their attitudes towards climate change, scientists, and energy efficiency, together with their feelings of agency regarding government and businesses' actions. The section on behaviours asked respondents about behavioural activities, such as paying more for environmental products or turning down heating in rooms. The same 5-point Likert scale was used for the affective and behavioural domains, and examples of individual and social actions were included. Higher scores on these scales generally denote more positive attitudes toward energy-related issues or more effective energy-saving behaviours.

The analyses were performed as mentioned below

(i) descriptive analysis;
(ii) factor analysis to identify the dimensions of attitudes and behaviour;
(iii) regression analysis to identify which dimensions are the most explanatory of energy use;

(iv) analysis of variance, to identify statistically significant differences between countries.

It must be stressed that this survey was undertaken before the pandemic. The survey was open for a long period, but responses tailed off after two months. The survey was made available to students via institutional webpages or direct emails from administrative staff. For ethical reasons, the students were told that the survey was about energy, which may have encouraged more knowledgeable students to respond. The authors are aware of the sample's limitations; however, the overall number of respondents in each institution was high, and respondents were broadly speaking representative of those in the whole institution.

4. Results and Discussion

[1] https://www.researchgate.net/publication/341179747_Energy_Literacy_Survey_Debby_Cotton

In this section we present and discuss the descriptive statistics for each dimension of attitude and behavioural intentions, the factor analysis results (for attitudes and behavioural intentions), the tests of differences in means, and the linear regression model offering an explanation of students' use of energy. We explore similarities and differences between the two institutions, as well as comparing findings to previous research using the energy literacy survey.

4.1 Sustainable Attitudes Scale.

The internal reliability index of the Sustainable Attitudes scale, measured using Cronbach's alpha, was 0.600, representing a satisfactory internal reliability level (Hair *et al*., 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.613 (Bartlett's Sphericity Test (p <0.00)), a result that points to the factorability of the data. The analysis employed Principal Component Analysis (PCA) with varimax rotation and listwise treatment for missing values. Factor analysis was performed in 4 iterations. The final model showed three dimensions of sustainable attitudes: Citizens' Role, Scientists' Role, and Government's Role (Table 2). The total explained variance was 65.522% with the Citizens' Role dimension explaining 23.560%, the Scientists' Role, 21.332%, and the Government's Role, 20.630%.

Table 2. Factorial results for attitudes

Dimension	Items	Factor Loading	Mean	Standard deviation
Citizens' Role	A3 – I can influence what the government does about energy problems.	0.871	2.59	1.032
	A4 – I can influence what companies do about energy problems.	0.876	2.60	1.035
Scientists' Role	A6 - Scientists will find ways to solve energy problems.	0.895	3.40	1.019
	A9 - Climate change has been established as a serious problem and immediate action is necessary.	0.790	3.30	1.428
Government's Role	A10 - Climate change is caused by human activities related to using energy	0.758	3.80	0.863
	A8 - The government should have stronger standards on fuel efficiency of cars.	0.754	3.82	0.964
	A7 - More wind farms should be developed to generate electricity, even if they are located in scenic environments.	0.518	3.41	1.080

1-Strongly disagree, 2- Disagree, 3 Neither agree or disagree, 4-Agree, 5- Strongly agree

The Citizens' Role dimension (M = 2.59; SD = 1.850) includes the variables: (i) "I can influence what the government does about energy problems"; and (ii) "I can influence what companies do about energy problems". This dimension was the one that presented the lowest averages, which suggests that respondents are generally ambivalent or slightly disagree that they can influence government action. This finding has been reported in almost all contexts where the survey has been used. In the UK, students were consistently less confident about their ability to influence others than to engage in personal behaviour change: "the overriding story is one of limited agency, exacerbated by respondents' low incomes and perceived powerlessness" (Cotton *et al.*, 2016a, p. 894). In Portugal, students expressed somewhat stronger agency than those in the UK (Cotton *et al.*, 2016b), and in China, this was one of the most vital elements of the student response, perhaps reflecting a more

collectivist culture (Cotton *et al.*, 2021). Similar results were found in Mulder *et al.* (2010), which analysed the learning outcomes of 500 students from five European Technological Universities concerning the sustainable development and the pedagogical approach adopted. The results demonstrate that students initially perceived sustainability mainly related to technological aspects, believing that technology can offer solutions to environmental problems and perceived little relevance of sustainability's social and behavioural aspects.

For environmental problems to be minimized and for an improvement in environmental quality to occur, changing individuals and society's behaviour is fundamental to improving environmental and life quality - this is an issue that requires an educational process and environmental awareness (Lozano *et al.*, 2019). The Scientists' Role dimension (M = 3.34; SD = 1.059) includes the variables: (i) "Scientists will find ways to solve energy problems"; and (ii) "Climate change has been established as a serious problem, and immediate action is necessary". This dimension had an average higher than 3.0, indicating that respondents believe in climate change and are confident about scientists' role in solving the climate crisis. All groups were considerably more likely to think that scientists will find solutions than that governments will act, which echoes the UK and Portuguese findings (Cotton *et al.*, 2016a and b), but the reverse was found in the Chinese sample (Cotton *et al.*, 2021). These results are in line with the study by Nejati and Nejati (2013), which also evaluated students' perception of the university's performance in creating partnerships with the government, non-governmental organizations, and the industry working towards sustainability. Leal Filho and colleagues (2015) showed that the government's role must go beyond financial support for universities, in encouraging universities to make education more flexible for sustainability and identifying opportunities in the green economy.

The third dimension, Government's Role (M = 3.67; SD = 1.991) includes the variables: (i) "Climate change is caused by human activities related to using energy"; (ii) "The government should have stronger standards on the fuel efficiency of cars."; and (iii) "More wind farms should be developed to generate electricity, even if they are in scenic environments". This dimension was the one that presented the highest averages, which suggests that respondents agree with the statements. Again, this echoes findings in the UK and Portugal (Cotton *et al.*, 2016b) but contrasts with China's findings (Cotton *et al.*, 2021), perhaps reflecting the more significant cultural similarity with the UK and Portuguese contexts of these groups of students.

4.2 Sustainable Behaviours Scale.

The internal reliability index of the Sustainable Behaviours scale, measured using Cronbach's alpha, was 0.620, representing a satisfactory internal reliability level (Hair *et al.*, 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.644 (Bartlett's Sphericity Test ($p < 0.00$)), a result that points to the factorability of the data. The factor analysis employed the Principal Component Analysis (PCA) with varimax rotation and listwise treatment for missing values. Factor analysis was performed in 5 iterations. The final model showed three dimensions of sustainable behaviours (Table 3). A total explained variance was 64.543%; the Consumption of eco-friendly products explains 23.395%, Financially-driven behaviour 20.871%, and Household energy-saving 20.278%.

Table 3. Factorial results for behaviours

Dimension	Items	Factor Loading	Mean	Standard deviation
Consumption of eco-friendly products	B17 - Buy things that are likely to involve less energy or resource use.	0.823	2.35	0,822
	B18 - Pay a bit more for environmentally friendly products.	0.860	2.41	0.819
Financially driven behaviours	B19 - Avoid charging mobile phones overnight.	0.798	2.31	1.084
	B20 - Turn off the stand-by button of the TV set or switch appliances off at the plug.	0.766	2.60	1.117
Household energy saving	B13 - Turn off lights when they are not in use.	0.737	3.63	0.561
	B14 - Turn down the heat or air conditioning.	0.727	3.21	0.875
	B15 - Try to save water.	0.589	3.02	0.785

1-never, 2-infrequently, 3-frequently, 4-always

The ordering of these behavioural items from most to least popular is remarkably similar across student populations in a wide range of contexts in which the survey has been used. Turning off lights is almost invariably the most popular energy-saving activity by students, suggesting that this behaviour is almost ubiquitous and automatic. Behaviours that involve financial outlay are generally less popular with students, reflecting, at least in part, their limited financial position. Avoiding charging phones overnight also often rates as less popular and is somewhat controversial, particularly as phone technology improves to reduce the risk of power usage when fully charged. This pattern of responses can be seen in the Portuguese and UK respondents (Cotton *et al.*, 2016b) but not in the Chinese sample (Cotton *et al.*, 2021).

4.3 Linear regression analysis.

The relationship between the dimensions of attitudes and behaviours and the variable "When it comes to energy use, how would you describe yourself" was tested by linear regression, using the stepwise method (Table 4). The energy use variable (M= 2.77; SD = 0.891) was assessed on a scale of 1 to 5, with 1 for respondents who consider themselves low energy users and 5 for respondents who consider themselves high energy users. The results of the linear regression show that three dimensions in the model are significant for the use of energy and represent 20.3% ($R2 = 0.203$, $p < 0.05$) of the overall use assessment: Scientists' Role, Consumption of Eco-friendly products, and Financially-driven behaviour. The Durbin-Watson test was employed to detect the presence of autocorrelation (dependence) in the residuals of a regression analysis (Hair *et al*., 2003). The model's test value (1.872) indicates that the residuals are independent (with a 95% confidence level).

In other words, the overall assessment of the use of energy depends significantly on the performance of these dimensions (Table 4). The model equation can be written as follows:

USE OF ENERGY = 0.210 + 0.381 * Scientists' Role – 0.150 * Consumption of Eco-friendly products – 0.139 * Financially-driven behaviour *{equation 1}*

Table 4. Linear regression model

Model	R	R Square	Adjusted R Square	St. Error of the Estimate	Durbin-Watson
1	0.391[a]	0.153	0.152	0.820	
2	0.435[b]	0.189	0.187	0.803	
3	0.454[c]	0.206	0.203	0.795	1.872

a. Predictors: (Constant), Scientists' Role

b. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products

c. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products, Financially-driven behaviour

The most important dimension in the assessment of energy use is "Scientists' role" (beta = 0.381; sig. 0.0000), which means that energy use increases with the belief that scientists will solve the energy problem and decreases as people consume more eco-friendly products and adopt more economy driven behaviours.

Table 5. Linear regression coefficients

Final Model	Unstandardized		Standardized	t	p
	B	Std. Error	Beta		
(Constant)	2.967	0.210		13.937	0.000
Scientists' Role	0.318	0.028	0.381	11.155	0.000
Consume of Eco-friendly products	-0.186	0.044	-0.150	-4.235	0.000
Economy driven behaviour	-0.234	0.059	-0.139	-3.953	0.000

4.4 Differences between Brazilian and Belgian respondents.

All dimensions showed significant differences for respondents from Brazil and Belgium. Only the Scientists' Role did not pass the homogeneity of variance test (Levene's test), but as the samples from Brazil (n = 376) and Belgium (n = 378) have sample' size variation of less than 10%, the homoscedasticity test does not affect the analysis of variance (Pestana and Gageiro, 2005). The ANOVA test allows us to conclude that there are significant differences between respondents from both countries for all dimensions of attitudes and behaviours.

Across all three attitudinal dimensions (Scientists 'role, Citizens' role and Government's role), Brazilian students scored more highly. Brazilian students expressed a strong faith in Science

(F=529.938; sig=0.000), indicating that Brazilian students have a strong belief that scientists will find ways to solve energy problems and that climate change demands immediate action. Brazilian students also felt more strongly about the Citizens' role (F=197.333; sig=0.000), expressing a stronger sense of agency and a stronger agency to influence the government and companies' actions. And finally, they expressed stronger support for the government taking a role in energy issues (F=23.444; sig=0.000) – for example by bringing in stronger standards on fuel efficiency in cars. In terms of the behavioural dimensions, Brazilian's students were more financially driven (F=38.351; sig=0.000) overall. Belgian students showed greater propensity for consumption of eco-friendly products (F=7.745; sig=0.000) and household energy saving (F=273.939; sig=0.000). A possible explanation might be linked to the fact that the average age of participants was higher at the Belgian institution and that they may have lower expectations of third parties (75.6% of the Brazilian respondents were under 25 years old, while 57.6% of the Belgian respondents are in that age group). Moreover, the typical Belgian governance structures (federal versus regional level) will also not promote "belief in government". The third layer from the EU may increase the complexity still further and thus reduce the trust in the government as a third partner for the Belgian participants.

Table 6. Institutional differences

	Belgium		Brazil	
Dimension	**Mean**	**SD**	**Mean**	**SD**
Attitudinal dimensions				
Scientists' role	2.667	0.939	4.035	0.653
Citizens' role	2.178	0.790	3.026	0.852
Government's role	3.560	0.646	3.792	0.661
Behavioural dimensions				
Consumption of eco-friendly products	2.459	0.697	2.313	0.735
Financially driven behaviour	3.173	0.508	3.407	0.518
Household energy saving	2.922	0.731	1.984	0.817

Despite the scepticism illustrated by their attitudinal positions, the Belgian respondents scored quite highly on the behavioural dimensions. It is known that an individual's behaviour is not always consistent with their attitudes. Bael (2009) has previously shown that people exhibit varied behaviours in different contexts and under the influence of different external and internal factors and actions may or may not be consistent with their underlying attitudes. Sometimes an individual's behaviour is influenced less by their underlying attitudes than by the prevailing social norms. This could be an explanation for the Belgian behavioural dimensions being mostly higher than the Brazilian ones. There are significant current initiatives within the University (PXL) to include sustainability in their policies which may have had a positive influence on their students' behaviour in comparison with Brazilian students.

In addition, the World Values Survey (Halpern, 2005; Inglehart, 2014) indicates that, historically, Brazil has been among the nations with a low social capital level and a downward trend. Social capital can be understood as the systems of participation and reciprocity that involve community

relations (Putnam, 1993). When social capital is less present, there is a tendency towards opportunism and selfish attitudes and behaviours since it implies that individuals can engage in the common good (Coleman, 1990; Inglehart, 2014). On the other hand, in Belgium, social capital levels are higher and tending to increase, showing a more communitarian spirit in attitudes and behaviours. However, further research would be needed to confirm this hypothesis. There are some interesting opportunities to explore the impact of personal, situational and behavioural variables on the relationship between attitudes and behaviour (Roberts *et al*., 2017). Analysing the cultural dimensions of both countries following the framework provided by Hofstede (2011) might also be informative in providing a better understanding of the differences between the countries and the ways in which they might influence individual behaviour. An analysis of the psychographics (e.g., lifestyles and values) would enrich future analysis.

5. Conclusions

This research involved deploying a widely used, rigorously tested energy literacy survey in two novel contexts, and using a new analytical approach. Three elements of sustainable attitudes and three elements of sustainable behaviours have been identified, and a linear regression analysis used to develop an equation linking certain attitudes and behavioural dimensions to overall energy usage. This enhanced theoretical model of individual energy use offers an additional tool to explore energy literacy in future research and suggests that overall energy use is positively related to consumption of eco-friendly products and financially driven behaviour but negatively related to a strong belief in science, suggesting a possible over-optimism about the role of scientists in solving energy problems. This new insight emphasises the need for care to be taken in educational contexts to ensure that students understand that there is a role for individual action as well as scientific advance and government regulation in combating climate change. Differences between the two contexts also emerged, with Brazilian students being generally more optimistic about the role of scientists, citizens, and the government than those in Belgium. Perhaps reflecting students' different economic circumstances in the two countries, those in Brazil were more financially motivated, and the Belgian students showed a greater propensity for consumption of eco-friendly products and household energy saving.

It is not clear that in either context, the attitudes and behaviours of respondents are sufficient to drive the level of change needed to avert the climate crisis. Echoing previous research in the UK and Portuguese context, this study notes the limited sense of agency felt by students both in Belgium and Brazil regarding influencing the actions of government or businesses. These are sobering findings, given the clear need for strong political action globally. There is also evidence that, like most of the students surveyed worldwide, the behaviours which were most undertaken were not those that save the most energy! Students in Belgium and Brazil, as with those in the UK and Portugal, were more likely to see turning off lights and other similar activities as playing a pivotal role, despite their limited impact on energy use overall. Findings differed significantly from the Chinese context, leaving this as an outlier where students had hugely different attitudes and behaviours towards energy saving. Further research on cultural context, and the implications for energy saving and sustainability education would be extremely valuable.

This paper contributes to a broader debate on strategies for implementation of ESD and education for sustainability (EfS) by mapping arguments on competencies for SD and sustainability with a particular focus on higher education institutions. Our findings suggest that: (i) universities should focus on individual behavioural changes alongside teaching sustainability science (to reduce the risk

that students rely on scientists to solve energy problems); (ii) governments should encourage public policies to raise awareness of the role of citizens in the sustainable use of energy; and (iii) universities should identify key elements for the construction of north-south cooperation proposals, such as capacity building programs for the dissemination of best sustainable practices. By identifying factors influencing students' perceptions of sustainability, and their energy saving activities, this study provides pertinent evidence for social researchers and university managers on ways in which the sustainable university ideal might be realised.

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Student Energy-Saving in Higher Education
Tackling the Challenge of Decarbonisation

Structured Abstract

Purpose:
This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in higher education settings.

Methodology:
We used a validated energy literacy survey to assess undergraduate students' attitudes and behavioural intentions towards energy-saving in two countries (Brazil and Belgium). The questionnaire, administered online, comprised 23 Likert scale questions and 3 questions eliciting socio-demographic information. Results were analyzed using a linear regression model and compared with previous research using the same energy literacy instrument.

Findings:
The research identified three dimensions of sustainable attitudes: Citizens' role, Scientists' role, and Government's role, explaining 65.5% of respondents' energy-related attitudes. Three dimensions of sustainable behaviours were identified, explaining 64.5% of energy-related behavioural intentions: Consumption of eco-friendly products, financially driven behaviours, and household energy saving. The linear regression model identified Scientists' Role, consumption of eco-friendly products and financially driven behaviour as the key predictors of student energy use. Differences between the two contexts also emerged.

Originality:
Student attitudes and behavioural intentions towards energy are an important element of campus decarbonisation and can act as a catalyst towards a carbon-free society. Although energy literacy research has been undertaken in the US and UK, this research is the first of its kind for Belgium and Brazil and the mode of analysis - using a linear regression model - differs from the earlier work, offering a novel methodological approach.

Keywords: Energy literacy; Decarbonisation; Campus

Article classification: Research paper

Student Energy-Saving in Higher Education: Tackling the Challenge of Decarbonisation

1. Introduction.

1.1. The energy problem

Demographic growth and increasing natural resource exploitation are environmental problems that worsen social issues such as health problems, extreme poverty, and social inequality (Pérez and Frank, 2019). With energy demands rising, and high levels of fossil fuel use, greenhouse gases in the Earth's atmosphere continue to increase, and CO_2 is currently at nearly 412 parts per million (ppm) and still rising. This represents a 47% increase since the beginning of the Industrial Age (Kappelle, 2020). According to the latest IPCC report (2021), 'human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years' (SPM-7). This is a crucial issue for humankind that requires an urgent response.

In Brazil, energy consumption was 16,325 KWh/p in 2019, while in Belgium, consumption was 65,303 KWh/p per person. Compared to 2018, energy consumption increased by 2.22% in Brazil and 4.79% in Belgium (Ritchie, 2021a). Concerning the share of primary energy from renewable sources in 2019 (including hydropower, solar, wind, geothermal, bioenergy, wave, and tidal), Brazil obtains 45.02% of energy from renewable sources, whereas Belgium uses only 6.94% renewables (Ritchie, 2021b).

Energy use in buildings represents 6.5% of direct and 12% of indirect emissions of CO_2 worldwide. To be successful in the transition towards a Post Fossil-Carbon Society, there is a need to reduce this type of energy consumption, as well as to minimize greenhouse gas emissions (EU, 2020; IPCC, 2021). The 'Energy Performance of Buildings Directive' in Europe required all new buildings to be nearly zero-energy by the end of 2020 (EU, 2020). However, additional efforts must be made for existing buildings as only about 1% of the building stock is renovated each year (Magrini *et al.*, 2020). In Brazil, since 2007, the certification body of the Leadership in Energy and Environmental Design (LEED) is the Green Building Council (GBC), which has already received 1,400 enrolments and issued 552 LEED certificates in commerce, industry, and services (UpperSolar, 2020). In both contexts, more work will be needed to meet challenging CO_2 reduction targets.

1.2 Energy and the Sustainable Development Goals.

An increasing number of universities and other Higher Education Institutions (HEIs) are seeking a Sustainable Development agenda for the future (Leal Filho et al., 2019). Historically, HEIs have played a key role in transforming societies, educating decision-makers, leaders and entrepreneurs (Nejati and Nejati, 2013). Their contribution to Energy Efficiency (EE) goals can be substantial beyond the facilities management realm in promoting individual action in staff and students, and undertaking research leading to policy changes. With the introduction of the Sustainable Development Goals (SDGs) (UN, 2015), there is now a clear structure to focus on, and the SDGs have become progressively more established in higher education (HE), frequently referred to in policies and curricula as students increasingly expect a sustainability focus. Engaging with the SDGs can offer benefits to institutions by demonstrating impact, capturing demand for sustainability education, building new partnerships, and accessing new funding streams. Education and research are explicitly recognized in several of the SDGs; thus HEIs, with their broad remit around the creation and dissemination of knowledge and their unique position within society, have a pivotal role to play in their achievement.

Higher Education increasingly needs to equip students with the necessary skills to comprehend and solve wicked problems (Weber *et al.*, 2021). This requires an interdisciplinary approach with new solutions for the economy and society, hence initiatives can often be linked to multiple SDGs. For example, EE projects can obviously have an impact on SDG 7 (sustainable energy), but are also likely to impact SDG 4 (education) and SDG 3 (wellbeing). There is an increasing focus on linking the educational aspects of sustainability with campus developments – encouraging students to undertake projects concerning use of energy in buildings for example. Educational buildings have enormous potential for improvements in energy efficiency. They represent a large volume managed by one single owner (in contrast with the private market). Moreover, they offer a forum to involve various stakeholders (facility managers, visitors, students, and teaching and research staff) with diverse backgrounds to create, support, and marshal evidence for energy conservation. In short, energy efficiency has a key role to play in the move towards using the campus as a living lab (see Franco et al., 2018; Mazutti et al., 2020) – combining student learning with carbon reduction aspirations.

1.3 Aims and Context of the Research

This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in HE. The research was conducted at two universities, PXL University of Applied Sciences in Belgium and the University of Caxias Do Sul in Brazil. It offers novel insights into how students understand energy, their attitudes towards it, and their energy-saving behavioural intentions. The survey has been previously undertaken in the UK, Portugal, and China (Cotton *et al*., 2015; 2016a; 2021). Its use in another European HEI offers the possibility to extend the reach of this survey, and by involving the University of Caxias Do Sul, the first comparison with a Latin American country is possible. This choice is no coincidence as, in 2019, Brazil was the first country in Latin America that is not a member of the International Energy Agency (IEA) to complete the Agency's efficiency indicators questionnaire. Brazil is a priority country in the Agency's Clean Energy Transitions Program (IEA, 2019), and thus offers an exciting new context to explore this issue.

2. Theoretical background and literature review.

2.1 Energy Literacy in Higher Education.

A significant literature on sustainable universities has been emerging over recent years as HEIs recognize the necessity to be seen as leaders in this field, and researchers increasingly turn their attention to their own institutions and sector. Moving beyond the early attempts at campus greening to embed and include student learning in sustainability teaching and research endeavours has proved challenging but rewarding where efforts have been successful. Despite varied national contexts, universities worldwide have made some progress towards the sustainable university model as laid out by Sterling *et al.*, 2013. For example, the recent review by Findler *et al*., (2019) indicates a broad range of research indicating direct and indirect impacts on sustainability arising from the activities of HEIs - though largely in the form of case studies of individual institutions or subjects.

An essential mode of linking campus environmental developments with broader sustainability education has been through energy literacy (DeWaters and Powers, 2011; Cotton *et al*., 2015).

Originating in the US through work by DeWaters and Powers (2011), energy literacy embeds cognitive, affective, and conative elements in a tripartite framework, including:

- knowledge and understanding about energy, its use, and impact on environment and
- attitudes and values, for example, on climate change and the significance of personal actions; and
- intentions/behaviours, for example, to promote energy conservation or to advocate change.

Energy literacy should "… empower people to make appropriate energy-related choices and embrace changes in the way we harness and consume energy." (DeWaters and Powers, 2011, p.1699). In other words, it is aimed at behaviour change – a theoretically contested area with several competing perspectives in the literature.

2.2 Behaviour change.

The literature on behaviour change motivators often refers to the Theory of Reasoned Action (Fishbein and Ajzen, 1975). This theory indicates that behaviour depends on pre-existing attitudes and subjective norms associated with the specific behaviour. It was later developed by Ajzen (1991) and renamed the Theory of Planned Behaviour which included an element of perceived agency. This idea has also been shown to be important in energy-saving behaviours, where students' sense of personal agency in terms of individual behaviour has been seen to be much stronger than their belief that they can influence others (Cotton *et al.*, 2016b). Notably, knowledge plays little role in these theories, and the widespread view has been that knowledge about sustainability issues is insufficient to prompt behaviour change (Blake, 1999; Kollmuss and Agyeman, 2002). Some research into behaviour change towards sustainability has taken a more expansive theoretical framing, using social models of behaviour change (e.g., Stern, 2000; Jackson, 2005). These posit that an individual's ability to change is influenced not only by their personal perspective but also by the surrounding infrastructure (e.g., bicycle lanes or recycling facilities) that supports or inhibits them from changing their behaviour. Social models of behaviour change include Social Practice Theory (Shove, 2010; Hargreaves, 2011) and Sustainable Transition Management (Rotmans *et al.*, 2001; Verbong and Loorbach, 2012). These are 'systems theory' approaches that aspire to changes to society rather than merely to individuals.

The way sustainability issues are framed may also have a significant impact on the likelihood of behavioural change. For example, research by Spence *et al.*, (2014) suggested that framing energy saving in terms of carbon dioxide reduction rather than money-saving could encourage behaviour change. However, other research has identified financial inducements as more effective than verbal encouragement when attempting to encourage 'green' purchasing (Lanzini and Thøgersen, 2014). Research into social marketing approaches to sustainability indicates that an unduly moralizing or fear-inducing message is ineffective in encouraging behaviour change and potentially unethical (French and Gordon, 2019), but that enhanced emotional arousal or engagement can prompt behaviour change (Jacobs and Harms, 2014). Roeser (2012) described emotions as the 'missing link' in encouraging pro-environmental behaviour change, and further evidence of the role of emotion in pro-environmental behaviour was found in experimental work by Morris *et al.*, (2019). A further concept of note is 'behavioural spillover' – which suggests that acting in a pro-environmental way may encourage people to engage in related pro-environmental activities as a protective response to avoid cognitive dissonance (Thøgersen, 1999). Barriers to behaviour change include inertia (habits are difficult to change) and lack of awareness of an issue (Hafner *et al.,* 2019). However, the habit

discontinuity hypothesis (Verplanken and Roy, 2016) suggests that a significant life change may prompt a re-evaluation of long-standing behaviour. Thus, for many students starting university may be an opportunity to make changes toward a more sustainable lifestyle.

2.3 Energy efficiency (EE).

Energy efficiency in HE can take multiple forms. Design of campus buildings, as well as behaviour change of the individuals that use them, are both important elements. In design terms, it is important to take account of the whole life cycle of a building, considering its carbon and material footprint (construction, renovation, retrofitting) (La Fleur et al., 2019). In terms of behaviour change, there is a need to consider technical, social, economic and educational aspects. Heating, ventilation, and air-conditioning (HVAC) is the primary source of energy consumption in most university buildings, and these are intimately inter-related with the actions of building users. Sanguinetti *et al*. (2017) stressed various energy efficiency goals in buildings: inspiring occupant participation, interpretation of the data, and improving comfort and energy efficiency. Kim *et al.* (2019) detailed the crucial role of facility managers in HE building EE projects. Whitney *et al.* (2020) mentioned the motivation, barriers, and leverage points to achieve an energy reduction for (commercial) buildings. In tandem with EE and energy flexibility, the introduction of renewable energy is an essential tool to realize a carbon-free society (*Blazquez et al.*, (2020).

There are various ways of trying to improve energy consumption in buildings, including the 'trias energetica' method which involves reducing demand, using renewable energy and limiting fossil fuel use as far as possible. An alternative is to utilize a Maintenance Energy Performing Contract (MEPC), which considers not only economic aspects but also incorporates comfort, maintenance, and energy reduction (*Bleyl et al*., 2019). Essential parameters for retrofitting (historic) buildings using an EPC were listed by Tantau (2020) – and they are mostly valid for other buildings. Education buildings have the advantage that they generally have one owner and deal with a large volume of users. Leal Filho *et al.*, (2019) summarised different approaches to EE used by HEIs including pooling buildings to start a deep building renovation, combined with projects with a shorter payback time (Franco *et al.*, 2019a and b and 2020). Another critical topic is engaging with students, the next generation of leaders, whereby co-creation is both desirable and achievable in terms of building design and use (Franco *et al.,* 2020).

3. Methods and context

3.1 Sample.

The universities involved in this study are PXL University of Applied Sciences (Belgium) and University of Caxias Do Sul (UCS) (Brazil), with 754 students in total participating. The PXL University of Applied Sciences is a centre of expertise for innovation, creativity, and entrepreneurship. The institution organizes all activities starting from the quadruple helix model (interaction between government, knowledge institutes, industry, and society). The university strives to work in an interdisciplinary way in both teaching and research, and this approach infuses into sustainability policies and projects. The quadruple helix approach illustrates the interaction with all stakeholders and the interdisciplinarity shows that EE projects incorporate economic benefits, as well as education, wellbeing, and community engagement.

The University of Caxias Do Sul (UCS) is a centre of innovation, creativity, and entrepreneurship focusing on sustainability. UCS takes part in the ranking of the best universities globally (Times Higher Education) and for the second consecutive year ranked as the most innovative university in Brazil among the community and private universities and positioned as one of the 20 most entrepreneurial companies in the country. Research activities include 28 Masters and Doctorate courses, and the university is also responsible for the training of teachers and professionals with high levels of creativity, resulting in 113 patent registrations at the National Institute of Industrial Property (INPI). The Research and Postgraduate programme bring together professors in 17 Research Centres, 21 Innovation and Development Centres, and 72 Research Groups. The university has 800 laboratories on eight campuses, 92 of which are specific for research related to the provision of services or consultancies. Given the proactive and problem-solving nature of entrepreneurial universities (Segers, 2020), it can be argued that these types of universities have a natural tendency to grapple with societal issues rather than merely engaging in activities that only generate an economic gain. According to Klofsten *et al*. (2019), an entrepreneurial approach will help university leaders to identify and deal with certain leadership challenges and strategic issues. One of the latter is the sustainable development agenda. Moreover, grappling with societal problems is a two-way street. Apart from the apparent benefits societies garner from university engagement, universities gain advantages too.

Figure 1. Key strategic challenges of the entrepreneurial university
(Klofsten *et al*., 2019 - adapted)

Table 1 Gender and age distribution

University	Gender	N (%)	Age	N (%)
Belgium	Male	155 (41.0 %)	20 or under	100 (26.5 %)
	Female	221 (58.5 %)	21-25	117 (31.0 %)
	Missing	1 (0.3%)	26-35	50 (13.2 %)
	Total	378 (100%)	36-47	48 (12.7 %)
			46-55	33 (8.7 %)
			Over 55	29 (7.7%)
			Missing	1 (0.3%)
			Total	378 (100 %)
Brazil	Male	214 (56.9%)	20 or under	105 (27.9 %)
	Female	158 (42.0 %)	21-25	158 (42.0 %)
	Missing	4 (1.1%)	26-35	71 (18.9 %)
	Total	376 (100%)	36-47	12 (3.2 %)
			46-55	2 (0.5 %)
			Over 55	0 (0%)
			Missing	28 (7.4%)
			Total	376 (100 %)

The sample consisted of 754 undergraduate students from Belgium (n = 378) and Brazil (n = 376). The demographics of student respondents are provided in table 1. Most participants in both institutions were under 25 years old, with the Brazilian university being more strongly weighted to younger students. At the Belgian university, most respondents were bachelor students (218 out of 378) but the survey was also carried out among the participants of after-training courses, which explains the slightly higher proportion of older students. The sample is balanced in terms of gender, with 50.7% female respondents, the Belgian sample being slightly female dominated and the Brazilian sample slightly male dominated. Brazilian students are from diverse fields of knowledge: engineering (35.2%) and exact sciences (23.3%), social sciences (29.9%), health sciences (10.6%), and arts and languages (1.0%). For Belgium, the students are also from diverse fields: technologies (31.7%), social sciences, economics, and communication (29.6%), exact sciences (2.8%), health sciences (20.3%), arts and languages (15.6%).

3.2 Survey and analysis

This study builds on the authors' existing work, exploring energy literacy amongst HE students (Cotton *et al.*, 2015; 2016 a & b). We explore participants' attitudes and behavioural intentions with different sustainability approaches using existing scales and validated instruments. The research involved an international team from the UK, Portugal, Brazil, and Belgium. The questionnaire was first translated into Brazilian Portuguese (for Brazilian respondents), Flemish, and English (for Belgian respondents), and then back translated to English to ensure the questions' readability and intelligibility. The original survey instrument contained 40 questions exploring energy knowledge, attitudes, and behavioural intentions and included a mixture of ranking, Likert-type scales, closed and open questions.

A version of the survey developed by Cotton *et al.* (2015) was used in this study, with some modifications to ensure accurate translation. (The survey instrument itself is available here)[1] This survey has been used in previous research in the UK, Portugal, and Belgium (Cotton *et al*., 2015; 2016 a & b; Franco *et al.*, 2018) and in China (Cotton *et al*., 2021). The section on attitudes asked survey respondents to respond statements about their attitudes towards climate change, scientists, and energy efficiency, together with their feelings of agency regarding government and businesses' actions. The section on behaviours asked respondents about behavioural activities, such as paying more for environmental products or turning down heating in rooms. The same 5-point Likert scale was used for the affective and behavioural domains, and examples of individual and social actions were included. Higher scores on these scales generally denote more positive attitudes toward energy-related issues or more effective energy-saving behaviours.

The analyses were performed as mentioned below

(i) descriptive analysis;
(ii) factor analysis to identify the dimensions of attitudes and behaviour;
(iii) regression analysis to identify which dimensions are the most explanatory of energy use;
(iv) analysis of variance, to identify statistically significant differences between countries.

It must be stressed that this survey was undertaken before the pandemic. The survey was open for a long period, but responses tailed off after two months. The survey was made available to students via institutional webpages or direct emails from administrative staff. For ethical reasons, the students were told that the survey was about energy, which may have encouraged more knowledgeable students to respond. The authors are aware of the sample's limitations; however, the overall number of respondents in each institution was high, and respondents were broadly speaking representative of those in the whole institution.

4. Results and Discussion

In this section we present and discuss the descriptive statistics for each dimension of attitude and behavioural intentions, the factor analysis results (for attitudes and behavioural intentions), the tests of differences in means, and the linear regression model offering an explanation of students' use of energy. We explore similarities and differences between the two institutions, as well as comparing findings to previous research using the energy literacy survey.

4.1 Sustainable Attitudes Scale.

The internal reliability index of the Sustainable Attitudes scale, measured using Cronbach's alpha, was 0.600, representing a satisfactory internal reliability level (Hair *et al*., 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.613 (Bartlett's Sphericity Test ($p < 0.00$)), a result that points to the factorability of the data. The analysis employed Principal Component Analysis (PCA) with varimax rotation and listwise treatment for missing values. Factor analysis was performed in 4 iterations. The final model showed three dimensions of sustainable attitudes: Citizens' Role, Scientists' Role, and Government's Role (Table 2). The total explained variance was 65.522% with the Citizens' Role dimension explaining 23.560%, the Scientists' Role, 21.332%, and the Government's Role, 20.630%.

[1] https://www.researchgate.net/publication/341179747_Energy_Literacy_Survey_Debby_Cotton

Table 2. Factorial results for attitudes

Dimension	Items	Factor Loading	Mean	Standard deviation
Citizens' Role	A3 – I can influence what the government does about energy problems.	0.871	2.59	1.032
	A4 – I can influence what companies do about energy problems.	0.876	2.60	1.035
Scientists' Role	A6 - Scientists will find ways to solve energy problems.	0.895	3.40	1.019
	A9 - Climate change has been established as a serious problem and immediate action is necessary.	0.790	3.30	1.428
Government's Role	A10 - Climate change is caused by human activities related to using energy	0.758	3.80	0.863
	A8 - The government should have stronger standards on fuel efficiency of cars.	0.754	3.82	0.964
	A7 - More wind farms should be developed to generate electricity, even if they are located in scenic environments.	0.518	3.41	1.080

Note: 1-Strongly disagree, 2- Disagree, 3 Neither agree or disagree, 4-Agree, 5- Strongly agree

The Citizens' Role dimension (M = 2.59; SD = 1.850) includes the variables: (i) "I can influence what the government does about energy problems"; and (ii) "I can influence what companies do about energy problems". This dimension was the one that presented the lowest averages, which suggests that respondents are generally ambivalent or slightly disagree that they can influence government action. This finding has been reported in almost all contexts where the survey has been used. In the UK, students were consistently less confident about their ability to influence others than to engage in personal behaviour change: "the overriding story is one of limited agency, exacerbated by respondents' low incomes and perceived powerlessness" (Cotton *et al.*, 2016a, p. 894). In Portugal, students expressed somewhat stronger agency than those in the UK (Cotton *et al.*, 2016b), and in China, this was one of the most vital elements of the student response, perhaps reflecting a more collectivist culture (Cotton *et al.*, 2021). Similar results were found in Mulder *et al.* (2010), which analysed the learning outcomes of 500 students from five European Technological Universities concerning the sustainable development and the pedagogical approach adopted. The results demonstrate that students initially perceived sustainability mainly related to technological aspects, believing that technology can offer solutions to environmental problems and perceived little relevance of sustainability's social and behavioural aspects.

For environmental problems to be minimized and for an improvement in environmental quality to occur, changing individuals and society's behaviour is fundamental to improving environmental and life quality - this is an issue that requires an educational process and environmental awareness (Lozano *et al.*, 2019). The Scientists' Role dimension (M = 3.34; SD = 1.059) includes the variables: (i) "Scientists will find ways to solve energy problems"; and (ii) "Climate change has been established as a serious problem, and immediate action is necessary". This dimension had an average higher than 3.0, indicating that respondents believe in climate change and are confident about scientists' role in solving the climate crisis. All groups were considerably more likely to think that scientists will find solutions than that governments will act, which echoes the UK and Portuguese findings (Cotton

et al., 2016a and b), but the reverse was found in the Chinese sample (Cotton *et al.*, 2021). These results are in line with the study by Nejati and Nejati (2013), which also evaluated students' perception of the university's performance in creating partnerships with the government, non-governmental organizations, and the industry working towards sustainability. Leal Filho and colleagues (2015) showed that the government's role must go beyond financial support for universities, in encouraging universities to make education more flexible for sustainability and identifying opportunities in the green economy.

The third dimension, Government's Role (M = 3.67; SD = 1.991) includes the variables: (i) "Climate change is caused by human activities related to using energy"; (ii) "The government should have stronger standards on the fuel efficiency of cars."; and (iii) "More wind farms should be developed to generate electricity, even if they are in scenic environments". This dimension was the one that presented the highest averages, which suggests that respondents agree with the statements. Again, this echoes findings in the UK and Portugal (Cotton *et al.*, 2016b) but contrasts with China's findings (Cotton *et al.*, 2021), perhaps reflecting the more significant cultural similarity with the UK and Portuguese contexts of these groups of students.

4.2 Sustainable Behaviours Scale.

The internal reliability index of the Sustainable Behaviours scale, measured using Cronbach's alpha, was 0.620, representing a satisfactory internal reliability level (Hair *et al.*, 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.644 (Bartlett's Sphericity Test (p <0.00)), a result that points to the factorability of the data. The factor analysis employed the Principal Component Analysis (PCA) with varimax rotation and listwise treatment for missing values. Factor analysis was performed in 5 iterations. The final model showed three dimensions of sustainable behaviours (Table 3). A total explained variance was 64.543%; the Consumption of eco-friendly products explains 23.395%, Financially-driven behaviour 20.871%, and Household energy-saving 20.278%.

Table 3. Factorial results for behaviours

Dimension	Items	Factor Loading	Mean	Standard deviation
Consumption of eco-friendly products	B17 - Buy things that are likely to involve less energy or resource use.	0.823	2.35	0,822
	B18 - Pay a bit more for environmentally friendly products.	0.860	2.41	0.819
Financially driven behaviours	B19 - Avoid charging mobile phones overnight.	0.798	2.31	1.084
	B20 - Turn off the stand-by button of the TV set or switch appliances off at the plug.	0.766	2.60	1.117
Household energy saving	B13 - Turn off lights when they are not in use.	0.737	3.63	0.561
	B14 - Turn down the heat or air conditioning.	0.727	3.21	0.875
	B15 - Try to save water.	0.589	3.02	0.785

1-never, 2-infrequently, 3-frequently, 4-always

The ordering of these behavioural items from most to least popular is remarkably similar across student populations in a wide range of contexts in which the survey has been used. Turning off lights is almost invariably the most popular energy-saving activity by students, suggesting that this behaviour is almost ubiquitous and automatic. Behaviours that involve financial outlay are generally less popular with students, reflecting, at least in part, their limited financial position. Avoiding charging phones overnight also often rates as less popular and is somewhat controversial, particularly as phone technology improves to reduce the risk of power usage when fully charged. This pattern of responses can be seen in the Portuguese and UK respondents (Cotton *et al.*, 2016b) but not in the Chinese sample (Cotton *et al.*, 2021).

4.3 Linear regression analysis.

The relationship between the dimensions of attitudes and behaviours and the variable "When it comes to energy use, how would you describe yourself" was tested by linear regression, using the stepwise method (Table 4). The energy use variable (M= 2.77; SD = 0.891) was assessed on a scale of 1 to 5, with 1 for respondents who consider themselves low energy users and 5 for respondents who consider themselves high energy users. The results of the linear regression show that three dimensions in the model are significant for the use of energy and represent 20.3% (R2 = 0.203, p <0.05) of the overall use assessment: Scientists' Role, Consumption of Eco-friendly products, and financially driven behaviour. The Durbin-Watson test was employed to detect the presence of autocorrelation (dependence) in the residuals of a regression analysis (Hair *et al*., 2003). The model's test value (1.872) indicates that the residuals are independent (with a 95% confidence level).

In other words, the overall assessment of the use of energy depends significantly on the performance of these dimensions (Table 4). The model equation can be written as follows:

USE OF ENERGY = 0.210 + 0.381 * Scientists' Role – 0.150 * Consumption of Eco-friendly products – 0.139 * Financially-driven behaviour *{equation 1}*

Table 4. Linear regression model

Model[d]	R	R Square	Adjusted R Square	St. Error of the Estimate	Durbin-Watson
1	0.391[a]	0.153	0.152	0.820	
2	0.435[b]	0.189	0.187	0.803	
3	0.454[c]	0.206	0.203	0.795	1.872

a. Predictors: (Constant), Scientists' Role
b. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products
c. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products, Financially-driven behaviour
d. Dependent Variable: A12 - When it comes to energy use, how would you describe yourself

The most important dimension in the assessment of energy use is "Scientists' role" (beta = 0.381; sig. 0.0000), which means that energy use increases with the belief that scientists will solve the energy

problem and decreases as people consume more eco-friendly products and adopt more economy driven behaviours.

Table 5. Linear regression coefficients

Final Model[a]	Unstandardized		Standardized	t	p
	B	Std. Error	Beta		
(Constant)	2.967	0.210		13.937	0.000
Scientists' Role	0.318	0.028	0.381	11.155	0.000
Consume of Eco-friendly products	-0.186	0.044	-0.150	-4.235	0.000
Economy driven behaviour	-0.234	0.059	-0.139	-3.953	0.000

a. Dependent Variable: A12 - When it comes to energy use, how would you describe yourself

4.4 Differences between Brazilian and Belgian respondents.

All dimensions showed significant differences for respondents from Brazil and Belgium. Only the Scientists' Role did not pass the homogeneity of variance test (Levene's test), but as the samples from Brazil (n = 376) and Belgium (n = 378) have sample' size variation of less than 10%, the homoscedasticity test does not affect the analysis of variance (Pestana and Gageiro, 2005). The ANOVA test allows us to conclude that there are significant differences between respondents from both countries for all dimensions of attitudes and behaviours.

Across all three attitudinal dimensions (Scientists 'role, Citizens' role and Government's role), Brazilian students scored more highly. Brazilian students expressed a strong faith in Science (F=529.938; sig=0.000), indicating that Brazilian students have a strong belief that scientists will find ways to solve energy problems and that climate change demands immediate action. Brazilian students also felt more strongly about the Citizens' role (F=197.333; sig=0.000), expressing a stronger sense of agency and a stronger agency to influence the government and companies' actions. And finally, they expressed stronger support for the government taking a role in energy issues (F=23.444; sig=0.000) – for example by bringing in stronger standards on fuel efficiency in cars. In terms of the behavioural dimensions, Brazilian's students were more financially driven (F=38.351; sig=0.000) overall. Belgian students showed greater propensity for consumption of eco-friendly products (F=7.745; sig=0.000) and household energy saving (F=273.939; sig=0.000). A possible explanation might be linked to the fact that the average age of participants was higher at the Belgian institution and that they may have lower expectations of third parties (75.6% of the Brazilian respondents were under 25 years old, while 57.6% of the Belgian respondents are in that age group). Moreover, the typical Belgian governance structures (federal versus regional level) will also not promote "belief in government". The third layer from the EU may increase the complexity still further and thus reduce the trust in the government as a third partner for the Belgian participants.

Table 6. Institutional differences

Dimension	Belgium		Brazil	
	Mean	SD	Mean	SD
Attitudinal dimensions				
Scientists' role	2.667	0.939	4.035	0.653
Citizens' role	2.178	0.790	3.026	0.852
Government's role	3.560	0.646	3.792	0.661
Behavioural dimensions				
Consumption of eco-friendly products	2.459	0.697	2.313	0.735
Financially driven behaviour	3.173	0.508	3.407	0.518
Household energy saving	2.922	0.731	1.984	0.817

Despite the scepticism illustrated by their attitudinal positions, the Belgian respondents scored quite highly on the behavioural dimensions. It is known that an individual's behaviour is not always consistent with their attitudes. Bael (2009) has previously shown that people exhibit varied behaviours in different contexts and under the influence of different external and internal factors and actions may or may not be consistent with their underlying attitudes. Sometimes an individual's behaviour is influenced less by their underlying attitudes than by the prevailing social norms. This could be an explanation for the Belgian behavioural dimensions being mostly higher than the Brazilian ones. There are significant current initiatives within the University (PXL) to include sustainability in their policies which may have had a positive influence on their students' behaviour in comparison with Brazilian students.

In addition, the World Values Survey (Halpern, 2005; Inglehart, 2014) indicates that, historically, Brazil has been among the nations with a low social capital level and a downward trend. Social capital can be understood as the systems of participation and reciprocity that involve community relations (Putnam, 1993). When social capital is less present, there is a tendency towards opportunism and selfish attitudes and behaviours since it implies that individuals can engage in the common good (Coleman, 1990; Inglehart, 2014). On the other hand, in Belgium, social capital levels are higher and tending to increase, showing a more communitarian spirit in attitudes and behaviours. However, further research would be needed to confirm this hypothesis. There are some interesting opportunities to explore the impact of personal, situational and behavioural variables on the relationship between attitudes and behaviour (Roberts *et al*., 2017). Analysing the cultural dimensions of both countries following the framework provided by Hofstede (2011) might also be informative in providing a better understanding of the differences between the countries and the ways in which they might influence individual behaviour. An analysis of the psychographics (e.g., lifestyles and values) would enrich future analysis.

In Brazil, not so many HEI (9) are active on the SDGs or agenda 2030, despite addressing sustainability practices (Pontelli *et al*., 2019), demonstrating a gap to be filled regarding sustainable development especially in public institutions. This collaboration and exchange of information between the EU countries and more specific with the Belgian PXL UAS can make a priority of Energy Efficiency for the University of Caxias Do Sul.

PXL UAS is the first SDG pioneer in Belgium and rather an atypic illustration. As the institution organizes all activities starting from the quadruple helix model, i.e. interaction between government, knowledge institutes, industry, and society. The quadruple helix approach illustrates the interaction with all stakeholders and the interdisciplinarity shows to all of them that Energy Efficiency projects incorporate economic benefits, as well as education, wellbeing, and community engagement, which improves the actions and interpretations of these stakeholders (including the students).

5. Conclusions

This research involved deploying a widely used, rigorously tested energy literacy survey in two novel contexts, and using a new analytical approach. Three elements of sustainable attitudes and three elements of sustainable behaviours have been identified, and a linear regression analysis used to develop an equation linking certain attitudes and behavioural dimensions to overall energy usage. This enhanced theoretical model of individual energy use offers an additional tool to explore energy literacy in future research and suggests that overall energy use is positively related to consumption of eco-friendly products and financially driven behaviour but negatively related to a strong belief in science, suggesting a possible over-optimism about the role of scientists in solving energy problems. This new insight emphasises the need for care to be taken in educational contexts to ensure that students understand that there is a role for individual action as well as scientific advance and government regulation in combating climate change. Differences between the two contexts also emerged, with Brazilian students being generally more optimistic about the role of scientists, citizens, and the government than those in Belgium. Perhaps reflecting students' different economic circumstances in the two countries, those in Brazil were more financially motivated, and the Belgian students showed a greater propensity for consumption of eco-friendly products and household energy saving. Notice that previous studies have reported that energy consumption was higher in Brazil, thus this could be a way Belgium students ameliorate the problem.

It is not clear that in either context, the attitudes and behaviours of respondents are sufficient to drive the level of change needed to avert the climate crisis. It is also necessary to take into account the influence of the surrounding infrastructure, and the impact of the theory of change in society. Echoing previous research in the UK and Portuguese context, this study notes the limited sense of agency felt by students both in Belgium and Brazil regarding influencing the actions of government or businesses. These are sobering findings, given the clear need for strong political action globally. There is also evidence that, like most of the students surveyed worldwide, the behaviours which were most undertaken were not those that save the most energy! Students in Belgium and Brazil, as with those in the UK and Portugal, were more likely to see turning off lights and other similar activities as playing a pivotal role, despite their limited impact on energy use overall. Findings differed significantly from the Chinese context, leaving this as an outlier where students had hugely different attitudes and behaviours towards energy saving – with the Chinese respondents indicating less positive attitudes towards energy saving and a lower likelihood of making individual behaviour changes, but having a greater trust in government to act (Cotton *et al*. 2021). Further research on cultural context, and the implications for energy saving and sustainability education would be extremely valuable.

In terms of the behaviour change theories discussed earlier, our research illustrates the importance of attitudinal variables in influencing behaviour change (as per the theory of reasoned action), but

also considers perceived agency (added into the theory of planned behaviour) as a mediating variable. This issue is complex and in a sense our research adds weight to the social theories of behaviour change in expanding this notion of agency beyond the individual and their own lifestyle to include their perception of being able to influence other bodies (government and companies). Looking more deeply still, we can observe a tension between the positive impact on behaviour change of feeling that one can influence others' behaviours (such as government and companies) and thus promoting forms of political and social action, and the negative impact of feeling that – as in this instance – scientists will be able to solve all the energy problems. There's a delicate balance to be found here between encouraging a trust in science – but without allowing people to externalise the responsibility for climate change mitigation onto another group (scientists). The precise ways and extent to which local subjective norms and available infrastructure in each setting impact on actual energy-saving behaviours would be worthy of further research.

This paper contributes to a broader debate on strategies for implementation of ESD and education for sustainability (EfS) by mapping arguments on competencies for SD and sustainability with a particular focus on higher education institutions. Our findings suggest that: (i) universities should focus on individual behavioural changes alongside teaching sustainability science (to reduce the risk that students rely on scientists to solve energy problems); (ii) governments should encourage public policies to raise awareness of the role of citizens in the sustainable use of energy; and (iii) universities should identify key elements for the construction of north-south cooperation proposals, such as capacity building programs for the dissemination of best sustainable practices. By identifying factors influencing students' perceptions of sustainability, and their energy saving activities, this study provides pertinent evidence for social researchers and university managers on ways in which the sustainable university ideal might be realised.

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Student Energy-Saving in Higher Education
Tackling the Challenge of Decarbonisation

Structured Abstract

Purpose:
This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in higher education settings.

Methodology:
We used a validated energy literacy survey to assess undergraduate students' attitudes and behavioural intentions towards energy-saving in two countries (Brazil and Belgium). The questionnaire, administered online, comprised 23 Likert scale questions and 3 questions eliciting socio-demographic information. Results were analyzed using a linear regression model and compared with previous research using the same energy literacy instrument.

Findings:
The research identified three dimensions of sustainable attitudes: Citizens' role, Scientists' role, and Government's role, explaining 65.5% of respondents' energy-related attitudes. Three dimensions of sustainable behaviours were identified, explaining 64.5% of energy-related behavioural intentions: Consumption of eco-friendly products, financially driven behaviours, and household energy saving. The linear regression model identified Scientists' Role, consumption of eco-friendly products and financially driven behaviour as the key predictors of student energy use. Differences between the two contexts also emerged.

Originality:
Student attitudes and behavioural intentions towards energy are an important element of campus decarbonisation and can act as a catalyst towards a carbon-free society. Although energy literacy research has been undertaken in the US and UK, this research is the first of its kind for Belgium and Brazil and the mode of analysis - using a linear regression model - differs from the earlier work, offering a novel methodological approach.

Keywords: Energy literacy; Decarbonisation; Campus

Article classification: Research paper

Student Energy-Saving in Higher Education: Tackling the Challenge of Decarbonisation

1. Introduction.

1.1. The energy problem

Demographic growth and natural resource exploitation at increasing rates are environmental problems that worsen social issues such as health problems, extreme poverty, and social inequality (Pérez and Frank, 2019). With energy demands rising, and high levels of fossil fuel use, greenhouse gases in the Earth's atmosphere continue to increase, and CO_2 is currently at nearly 412 parts per million (ppm) and still rising. This represents a 47% increase since the beginning of the Industrial Age (World Meteorological Organization, 2019). According to the latest IPCC report (2021), 'human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years' (SPM-7). This is a crucial issue for humankind that requires an urgent response.

In Brazil, energy consumption was 16,325 KWh/p in 2019, while in Belgium, consumption was 65,303 KWh/p per person. Compared to 2018, energy consumption increased by 2.22% in Brazil and 4.79% in Belgium (Ritchie, 2021). Concerning the share of primary energy from renewable sources in 2019 (including hydropower, solar, wind, geothermal, bioenergy, wave, and tidal), Brazil obtains 45.02% of energy from renewable sources, whereas Belgium uses only 6.94% renewables (Ritchie, 2021).

Energy use in buildings represents 6.5% of direct and 12% of indirect emissions of CO_2 worldwide. Thus, to be successful in the transition towards a Post Fossil-Carbon Society, there is a need to reduce this type of energy consumption, as well as to minimize greenhouse gas emissions (EU, 2020; IPCC, 2021). The 'Energy Performance of Buildings Directive' in Europe required all new buildings to be nearly zero-energy by the end of 2020. However, additional efforts must be made for existing buildings as only about 1% of the building stock is renovated each year (Magrini *et al.*, 2020). In Brazil, since 2007, the certification body of the Leadership in Energy and Environmental Design (LEED) is the Green Building Council (GBC), which has already received 1,400 enrolments and issued 552 LEED certificates in commerce, industry, and services (UpperSolar, 2020). In both contexts, more work will be needed to meet challenging CO_2 reduction targets.

1.2 Energy and the Sustainable Development Goals.

An increasing number of universities and other Higher Education Institutions (HEIs) are seeking a Sustainable Development agenda for the future (Leal Filho et al., 2019). Historically, HEIs have played a key role in transforming societies, educating decision-makers, leaders and entrepreneurs (Nejati and Nejati, 2013). Their contribution to Energy Efficiency (EE) goals can be substantial beyond the facilities management realm in promoting individual action in staff and students, and undertaking research leading to policy changes. With the introduction of the Sustainable Development Goals (SDGs) (UN, 2015), there is now a clear structure for HEIs to focus on, and the SDGs have become progressively more established in higher education (HE), frequently referred to in sustainability policies and curricula as students increasingly expect a sustainability focus. Engaging with the SDGs can offer benefits to institutions by demonstrating impact, capturing demand for sustainability education, building new partnerships and accessing new funding streams. Education and research are explicitly recognized in several of the SDGs; thus HEIs, with their broad remit around the creation and dissemination of knowledge and their unique position within society, have a pivotal role to play in their achievement.

Higher Education increasingly needs to equip students with the necessary skills to comprehend and solve wicked problems (Weber *et al.*, 2021). This requires an interdisciplinary approach with new solutions for the economy and society, hence initiatives can often be linked to multiple SDGs. For example, EE projects can obviously have an impact on SDG 7 (sustainable energy), but are also likely to impact SDG 4 (education) and SDG 3 (wellbeing). There is an increasing focus on linking the educational aspects of sustainability with campus developments – encouraging students to undertake projects concerning use of energy in buildings for example. Educational buildings have enormous potential for improvements in energy efficiency. They represent a large volume managed by one single owner (in contrast with the private market). Moreover, they offer a forum to involve various stakeholders (facility managers, visitors, students, and teaching and research staff) with diverse backgrounds to create, support, and marshal evidence for energy conservation. In short, energy efficiency has a key role to play in the move towards using the campus as a living lab (see Franco *et al.*, 2018; Mazutti *et al*., 2020) – combining student learning with carbon reduction aspirations.

1.3 Aims and Context of the Research

This research aimed to explore students' sustainability attitudes and behavioural intentions and their relation to energy use, to promote energy saving and decarbonisation in HE. The research was conducted at two universities, PXL University of Applied Sciences in Belgium and the University of Caxias Do Sul in Brazil. It offers novel insights into how students understand energy, their attitudes towards it, and their energy-saving behavioural intentions. The survey has been previously undertaken in the UK, Portugal, and China (Cotton *et al*., 2015; 2016a; 2021). Its use in another European HEI offers the possibility to extend the reach of this survey, and by involving the University of Caxias Do Sul, the first comparison with a Latin American country is possible. This choice is no coincidence as, in 2019, Brazil was the first country in Latin America that is not a member of the International Energy Agency (IEA) to complete the Agency's efficiency indicators questionnaire. Brazil is a priority country in the Agency's Clean Energy Transitions Program (IEA, 2019), and thus offers and exciting new context to explore this issue.

2. Theoretical background and literature review.

2.1 Energy Literacy in Higher Education.

A significant literature on sustainable universities has been emerging over recent years as HEIs recognize the necessity to be seen as leaders in this field, and researchers increasingly turn their attention to their own institutions and sector. Moving beyond the early attempts at campus greening to embed and include student learning in sustainability teaching and research endeavours has proved challenging but rewarding where efforts have been successful. Despite varied national contexts, universities worldwide have made some progress towards a sustainable university model as laid out by Sterling *et al.*, 2013. For example, the recent review by Findler *et al*., (2019) indicates a broad range of research indicating direct and indirect impacts on sustainability arising from the activities of HEIs - though largely in the form of case studies of individual institutions or subjects.

An essential mode of linking campus environmental developments with broader sustainability education has been through energy literacy (DeWaters and Powers, 2011; Cotton *et al*., 2015). Originating in the US through work by DeWaters and Powers (2011), energy literacy embeds cognitive, affective, and conative elements in a tripartite framework, including:

- knowledge and understanding about energy, its use, and impact on environment and
- attitudes and values, for example, on climate change and the significance of personal actions; and
- intentions/behaviours, for example, to promote energy conservation or to advocate change.

Energy literacy should "… empower people to make appropriate energy-related choices and embrace changes in the way we harness and consume energy." (DeWaters and Powers, 2011, p.1699). In other words, it is aimed at behaviour change – a theoretically contested area with several competing perspectives in the literature.

2.2 Behaviour change.

The literature on behaviour change motivators often refers to the Theory of Reasoned Action (Fishbein and Ajzen, 1975). This theory indicates that behaviour depends on pre-existing attitudes and subjective norms associated with the specific behaviour. It was later developed by Ajzen (1991) and renamed the Theory of Planned Behaviour which included an element of perceived agency. This idea has also been shown to be important in energy-saving behaviours, where students' sense of personal agency in terms of individual behaviour has been seen to be much stronger than their belief that they can influence others (Cotton *et al.*, 2016b). Notably, knowledge plays little role in these theories, and the widespread view has been that knowledge about sustainability issues is insufficient to prompt behaviour change (Blake, 1999; Kollmuss and Agyeman, 2002). Some research into behaviour change towards sustainability has taken a more expansive theoretical framing, using social models of behaviour change (e.g., Stern, 2000; Jackson, 2005). These posit that an individual's ability to change is influenced not only by their personal perspective but also by the surrounding infrastructure (e.g., bicycle lanes or recycling facilities) that supports or inhibits them from changing their behaviour. Social models of behaviour change include Social Practice Theory (Shove, 2010; Hargreaves, 2011) and Sustainable Transition Management (Rotmans *et al.*, 2001; Verbong and Loorbach, 2012). These are 'systems theory' approaches that aspire to changes to society rather than merely to individuals.

The way sustainability issues are framed may also have a significant impact on the likelihood of behavioural change. For example, research by Spence *et al.*, (2014) suggested that framing energy saving in terms of carbon dioxide reduction rather than money-saving could encourage behaviour change. However, other research has identified financial inducements as more effective than verbal encouragement when attempting to encourage 'green' purchasing (Lanzini and Thøgersen, 2014). Research into social marketing approaches to sustainability indicates that an unduly moralizing or fear-inducing message is ineffective in encouraging behaviour change and potentially unethical (French and Gordon, 2019), but that enhanced emotional arousal or engagement can prompt behaviour change (Jacobs and Harms, 2014). Roeser (2012) described emotions as the 'missing link' in encouraging pro-environmental behaviour change, and further evidence of the role of emotion in pro-environmental behaviour was found in experimental work by Morris *et al.*, (2019). A further concept of note is 'behavioural spillover' – which suggests that acting in a pro-environmental way may encourage people to engage in related pro-environmental activities as a protective response to avoid cognitive dissonance (Thøgersen, 1999). Barriers to behaviour change include inertia (habits are difficult to change) and lack of awareness of an issue (Hafner *et al.,* 2019). However, the habit discontinuity hypothesis (Verplanken and Roy, 2016) suggests that a significant life change may prompt a re-evaluation of long-standing behaviour. Thus, for many students starting university may be an opportunity to make changes toward a more sustainable lifestyle.

2.3 Energy efficiency (EE).

Energy efficiency in HE can take multiple forms. Design of campus buildings, as well as behaviour change of the individuals that use them, are both important elements. In design terms, it is important to take account of the whole life cycle of a building, considering its carbon and material footprint (construction, renovation, retrofitting) (La Fleur et al., 2019). In terms of behaviour of change, there is a need to consider technical, social, economic and educational aspects. Heating, ventilation, and air-conditioning (HVAC) is the primary source of energy consumption in most university buildings, and these are intimately inter-related with the actions of building users. Sanguinetti *et al*. (2017) stressed various energy efficiency goals in buildings: inspiring occupant participation, interpretation of the data, and improving comfort and energy efficiency. Kim *et al.* (2019) detailed the crucial role of facility managers in HE building EE projects. Whitney *et al.* (2020) mentioned the motivation, barriers, and leverage points to achieve an energy reduction for (commercial) buildings. In tandem with EE and energy flexibility, the introduction of renewable energy is an essential tool to realize a carbon-free society (*Blazquez et al.*, (2020).

There are various ways of trying to improve energy consumption in buildings, including the 'trias energetica' method which involves reducing demand, using renewable energy and limiting fossil fuel use as far as possible. An alternative is to utilize a Maintenance Energy Performing Contract (MEPC), which considers not only economic aspects but also incorporates comfort, maintenance, and energy reduction (*Bleyl et al*., 2019). Essential parameters for retrofitting (historic) buildings using an EPC were listed by Tantau (2020) – and they are mostly valid for other buildings. Education buildings have the advantage that they generally have one owner and deal with a large volume of users. Filho *et al.*, (2019) summarised different approaches to EE used by HEIs including pooling buildings to start a deep building renovation, combined with projects with a shorter payback time (Franco *et al.*, 2019 and 2020). Another critical topic is engaging with students, the next generation of leaders, whereby co-creation is both desirable and achievable in terms of building design and use (Franco *et al.,* 2020).

3. Methods and context

3.1 Sample.

The universities involved in this study are PXL University of Applied Sciences (Belgium) and University of Caxias Do Sul (UCS) (Brazil), with 754 students in total participating. The PXL University of Applied Sciences is a centre of expertise for innovation, creativity, and entrepreneurship. The institution organizes all activities starting from the quadruple helix model (interaction between government, knowledge institutes, industry, and society). The university strives to work in an interdisciplinary way in both teaching and research, and this approach infuses into sustainability policies and projects. The quadruple helix approach illustrates the interaction with all stakeholders and the interdisciplinarity shows that EE projects incorporate economic benefits, as well as education, wellbeing, and community engagement.

The University of Caxias Do Sul (UCS) is a centre of innovation, creativity, and entrepreneurship focusing on sustainability. UCS takes part in the ranking of the best universities globally (Times Higher Education) and for the second consecutive year ranked as the most innovative university in Brazil among the community and private universities and positioned as one of the 20 most entrepreneurial companies in the country. Research activities include 28 Masters and Doctorate

courses, and the university is also responsible for the training of teachers and professionals with high levels of creativity, resulting in 113 patent registrations at the National Institute of Industrial Property (INPI). The Research and Postgraduate programme brings together professors in 17 Research Centres, 21 Innovation and Development Centres, and 72 Research Groups. The university has 800 laboratories on eight campuses, 92 of which are specific for research related to the provision of services or consultancies.

Table 1 Gender and age distribution

University	Gender	N (%)	Age	N (%)
Belgium	Male	155 (41.0 %)	20 or under	100 (26.5 %)
	Female	221 (58.5 %)	21-25	117 (31.0 %)
	Missing	1 (0.3%)	26-35	50 (13.2 %)
	Total	378 (100%)	36-47	48 (12.7 %)
			46-55	33 (8.7 %)
			Over 55	29 (7.7%)
			Missing	1 (0.3%)
			Total	378 (100 %)
Brazil	Male	214 (56.9%)	20 or under	105 (27.9 %)
	Female	158 (42.0 %)	21-25	158 (42.0 %)
	Missing	4 (1.1%)	26-35	71 (18.9 %)
	Total	376 (100%)	36-47	12 (3.2 %)
			46-55	2 (0.5 %)
			Over 55	0 (0%)
			Missing	28 (7.4%)
			Total	376 (100 %)

The sample consisted of 754 undergraduate students from Belgium (n = 378) and Brazil (n = 376). The demographics of student respondents are provided in table 1. Most participants in both institutions were under 25 years old, with the Brazilian university being more strongly weighted to younger students. At the Belgian university, most respondents were bachelor students (218 out of 378) but the survey was also carried out among the participants of after-training courses, which explains the slightly higher proportion of older students. The sample is balanced in terms of gender, with 50.7% female respondents, the Belgian sample being slightly female dominated and the Brazilian sample slightly male dominated. Brazilian students are from diverse fields of knowledge: engineering (35.2%) and exact sciences (23.3%), social sciences (29.9%), health sciences (10.6%), and arts and languages (1.0%). For Belgium, the students are also from diverse fields: technologies (31.7%), social sciences, economics, and communication (29.6%), exact sciences (2.8%), health sciences (20.3%), arts and languages (15.6%).

3.2 Survey and analysis

This study builds on the authors' existing work, exploring energy literacy amongst HE students (Cotton *et al.*, 2015; 2016 a & b). We explore participants' attitudes and behavioural intentions with different sustainability approaches using existing scales and validated instruments. The research involved an international team from the UK, Portugal, Brazil, and Belgium. The questionnaire was first translated into Brazilian Portuguese (for Brazilian respondents), Flemish,

and English (for Belgian respondents), and then back translated to English to ensure the questions' readability and intelligibility. The original survey instrument contained 40 questions exploring energy knowledge, attitudes, and behavioural intentions and included a mixture of ranking, Likert-type scales, closed and open questions.

A version of the survey developed by Cotton *et al.* (2015) was used in this study, with some modifications to ensure accurate translation. (The survey instrument itself is available here)[1] This survey has been used in previous research in the UK, Portugal, and Belgium (Cotton *et al*., 2015; 2016 a & b; Franco *et al.*, 2018) and in China (Cotton *et al*., 2021). The section on attitudes asked survey respondents to respond statements about their attitudes towards climate change, scientists, and energy efficiency, together with their feelings of agency regarding government and businesses' actions. The section on behaviours asked respondents about behavioural activities, such as paying more for environmental products or turning down heating in rooms. The same 5-point Likert scale was used for the affective and behavioural domains, and examples of individual and social actions were included. Higher scores on these scales generally denote more positive attitudes toward energy-related issues or more effective energy-saving behaviours.

The analyses were performed as mentioned below

(i) descriptive analysis;
(ii) factor analysis to identify the dimensions of attitudes and behaviour;
(iii) regression analysis to identify which dimensions are the most explanatory of energy use;

(iv) analysis of variance, to identify statistically significant differences between countries.

It must be stressed that this survey was undertaken before the pandemic. The survey was open for a long period, but responses tailed off after two months. The survey was made available to students via institutional webpages or direct emails from administrative staff. For ethical reasons, the students were told that the survey was about energy, which may have encouraged more knowledgeable students to respond. The authors are aware of the sample's limitations; however, the overall number of respondents in each institution was high, and respondents were broadly speaking representative of those in the whole institution.

4. Results and Discussion

In this section we present and discuss the descriptive statistics for each dimension of attitude and behavioural intentions, the factor analysis results (for attitudes and behavioural intentions), the tests of differences in means, and the linear regression model offering an explanation of students' use of energy. We explore similarities and differences between the two institutions, as well as comparing findings to previous research using the energy literacy survey.

4.1 Sustainable Attitudes Scale.

The internal reliability index of the Sustainable Attitudes scale, measured using Cronbach's alpha, was 0.600, representing a satisfactory internal reliability level (Hair *et al*., 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.613 (Bartlett's Sphericity Test ($p < 0.00$)), a result that points to the factorability of the data. The analysis employed Principal Component Analysis (PCA) with

[1] https://www.researchgate.net/publication/341179747_Energy_Literacy_Survey_Debby_Cotton

varimax rotation and listwise treatment for missing values. Factor analysis was performed in 4 iterations. The final model showed three dimensions of sustainable attitudes: Citizens' Role, Scientists' Role, and Government's Role (Table 2). The total explained variance was 65.522% with the Citizens' Role dimension explaining 23.560%, the Scientists' Role, 21.332%, and the Government's Role, 20.630%.

Table 2. Factorial results for attitudes

Dimension	Items	Factor Loading	Mean	Standard deviation
Citizens' Role	A3 – I can influence what the government does about energy problems.	0.871	2.59	1.032
	A4 – I can influence what companies do about energy problems.	0.876	2.60	1.035
Scientists' Role	A6 - Scientists will find ways to solve energy problems.	0.895	3.40	1.019
	A9 - Climate change has been established as a serious problem and immediate action is necessary.	0.790	3.30	1.428
Government's Role	A10 - Climate change is caused by human activities related to using energy	0.758	3.80	0.863
	A8 - The government should have stronger standards on fuel efficiency of cars.	0.754	3.82	0.964
	A7 - More wind farms should be developed to generate electricity, even if they are located in scenic environments.	0.518	3.41	1.080

1-Strongly disagree, 2- Disagree, 3 Neither agree or disagree, 4-Agree, 5- Strongly agree

The Citizens' Role dimension (M = 2.59; SD = 1.850) includes the variables: (i) "I can influence what the government does about energy problems"; and (ii) "I can influence what companies do about energy problems". This dimension was the one that presented the lowest averages, which suggests that respondents are generally ambivalent or slightly disagree that they can influence government action. This finding has been reported in almost all contexts where the survey has been used. In the UK, students were consistently less confident about their ability to influence others than to engage in personal behaviour change: "the overriding story is one of limited agency, exacerbated by respondents' low incomes and perceived powerlessness" (Cotton *et al.*, 2016a, p. 894). In Portugal, students expressed somewhat stronger agency than those in the UK (Cotton *et al.*, 2016b), and in China, this was one of the most vital elements of the student response, perhaps reflecting a more collectivist culture (Cotton *et al.*, 2021). Similar results were found in Mulder *et al.* (2010), which analysed the learning outcomes of 500 students from five European Technological Universities concerning the sustainable development and the pedagogical approach adopted. The results demonstrate that students initially perceived sustainability mainly related to technological aspects, believing that technology can offer solutions to environmental problems and perceived little relevance of sustainability's social and behavioural aspects.

For environmental problems to be minimized and for an improvement in environmental quality to occur, changing individuals and society's behaviour is fundamental to improving environmental and life quality - this is an issue that requires an educational process and environmental awareness (Lozano *et al.*, 2019). The Scientists' Role dimension (M = 3.34; SD = 1.059) includes the variables: (i)

"Scientists will find ways to solve energy problems"; and (ii) "Climate change has been established as a serious problem, and immediate action is necessary". This dimension had an average higher than 3.0, indicating that respondents believe in climate change and are confident about scientists' role in solving the climate crisis. All groups were considerably more likely to think that scientists will find solutions than that governments will act, which echoes the UK and Portuguese findings (Cotton *et al.*, 2016a and b), but the reverse was found in the Chinese sample (Cotton *et al.*, 2021). These results are in line with the study by Nejati and Nejati (2013), which also evaluated students' perception of the university's performance in creating partnerships with the government, non-governmental organizations, and the industry working towards sustainability. Leal Filho and colleagues (2015) showed that the government's role must go beyond financial support for universities, in encouraging universities to make education more flexible for sustainability and identifying opportunities in the green economy.

The third dimension, Government's Role (M = 3.67; SD = 1.991) includes the variables: (i) "Climate change is caused by human activities related to using energy"; (ii) "The government should have stronger standards on the fuel efficiency of cars."; and (iii) "More wind farms should be developed to generate electricity, even if they are in scenic environments". This dimension was the one that presented the highest averages, which suggests that respondents agree with the statements. Again, this echoes findings in the UK and Portugal (Cotton *et al*., 2016b) but contrasts with China's findings (Cotton *et al.*, 2021), perhaps reflecting the more significant cultural similarity with the UK and Portuguese contexts of these groups of students.

4.2 Sustainable Behaviours Scale.

The internal reliability index of the Sustainable Behaviours scale, measured using Cronbach's alpha, was 0.620, representing a satisfactory internal reliability level (Hair *et al.*, 2003). The KMO test (Kaiser-Meyer-Olkin) resulted in 0.644 (Bartlett's Sphericity Test ($p < 0.00$)), a result that points to the factorability of the data. The factor analysis employed the Principal Component Analysis (PCA) with varimax rotation and listwise treatment for missing values. Factor analysis was performed in 5 iterations. The final model showed three dimensions of sustainable behaviours (Table 3). A total explained variance was 64.543%; the Consumption of eco-friendly products explains 23.395%, Financially-driven behaviour 20.871%, and Household energy-saving 20.278%.

Table 3. Factorial results for behaviours

Dimension	Items	Factor Loading	Mean	Standard deviation
Consumption of eco-friendly products	B17 - Buy things that are likely to involve less energy or resource use.	0.823	2.35	0,822
	B18 - Pay a bit more for environmentally friendly products.	0.860	2.41	0.819
Financially driven behaviours	B19 - Avoid charging mobile phones overnight.	0.798	2.31	1.084
	B20 - Turn off the stand-by button of the TV set or switch appliances off at the plug.	0.766	2.60	1.117

Household energy saving	B13 - Turn off lights when they are not in use.	0.737	3.63	0.561
	B14 - Turn down the heat or air conditioning.	0.727	3.21	0.875
	B15 - Try to save water.	0.589	3.02	0.785

1-never, 2-infrequently, 3-frequently, 4-always

The ordering of these behavioural items from most to least popular is remarkably similar across student populations in a wide range of contexts in which the survey has been used. Turning off lights is almost invariably the most popular energy-saving activity by students, suggesting that this behaviour is almost ubiquitous and automatic. Behaviours that involve financial outlay are generally less popular with students, reflecting, at least in part, their limited financial position. Avoiding charging phones overnight also often rates as less popular and is somewhat controversial, particularly as phone technology improves to reduce the risk of power usage when fully charged. This pattern of responses can be seen in the Portuguese and UK respondents (Cotton *et al.*, 2016b) but not in the Chinese sample (Cotton *et al.*, 2021).

4.3 Linear regression analysis.

The relationship between the dimensions of attitudes and behaviours and the variable "When it comes to energy use, how would you describe yourself" was tested by linear regression, using the stepwise method (Table 4). The energy use variable (M= 2.77; SD = 0.891) was assessed on a scale of 1 to 5, with 1 for respondents who consider themselves low energy users and 5 for respondents who consider themselves high energy users. The results of the linear regression show that three dimensions in the model are significant for the use of energy and represent 20.3% (R2 = 0.203, p <0.05) of the overall use assessment: Scientists' Role, Consumption of Eco-friendly products, and Financially-driven behaviour. The Durbin-Watson test was employed to detect the presence of autocorrelation (dependence) in the residuals of a regression analysis (Hair *et al*., 2003). The model's test value (1.872) indicates that the residuals are independent (with a 95% confidence level).

In other words, the overall assessment of the use of energy depends significantly on the performance of these dimensions (Table 4). The model equation can be written as follows:

USE OF ENERGY = 0.210 + 0.381 * Scientists' Role – 0.150 * Consumption of Eco-friendly products – 0.139 * Financially-driven behaviour *{equation 1}*

Table 4. Linear regression model

Model	R	R Square	Adjusted R Square	St. Error of the Estimate	Durbin-Watson
1	0.391[a]	0.153	0.152	0.820	
2	0.435[b]	0.189	0.187	0.803	
3	0.454[c]	0.206	0.203	0.795	1.872

a. Predictors: (Constant), Scientists' Role
b. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products
c. Predictors: (Constant), Scientists' Role, Consume of Eco-friendly products, Financially-driven behaviour
d. Dependent Variable: A12 - When it comes to energy use, how would you describe yourself

The most important dimension in the assessment of energy use is "Scientists' role" (beta = 0.381; sig. 0.0000), which means that energy use increases with the belief that scientists will solve the energy problem and decreases as people consume more eco-friendly products and adopt more economy driven behaviours.

Table 5. Linear regression coefficients

Final Model	Unstandardized		Standardized	t	p
	B	Std. Error	Beta		
(Constant)	2.967	0.210		13.937	0.000
Scientists' Role	0.318	0.028	0.381	11.155	0.000
Consume of Eco-friendly products	-0.186	0.044	-0.150	-4.235	0.000
Economy driven behaviour	-0.234	0.059	-0.139	-3.953	0.000

a. Dependent Variable: A12 - When it comes to energy use, how would you describe yourself

4.4 Differences between Brazilian and Belgian respondents.

All dimensions showed significant differences for respondents from Brazil and Belgium. Only the Scientists' Role did not pass the homogeneity of variance test (Levene's test), but as the samples from Brazil (n = 376) and Belgium (n = 378) have sample' size variation of less than 10%, the homoscedasticity test does not affect the analysis of variance (Pestana and Gageiro, 2005). The ANOVA test allows us to conclude that there are significant differences between respondents from both countries for all dimensions of attitudes and behaviours.

Across all three attitudinal dimensions (Scientists 'role, Citizens' role and Government's role), Brazilian students scored more highly. Brazilian students expressed a strong faith in Science (F=529.938; sig=0.000), indicating that Brazilian students have a strong belief that scientists will find ways to solve energy problems and that climate change demands immediate action. Brazilian students also felt more strongly about the Citizens' role (F=197.333; sig=0.000), expressing a stronger sense of agency and a stronger agency to influence the government and companies' actions. And finally, they expressed stronger support for the government taking a role in energy issues (F=23.444; sig=0.000) – for example by bringing in stronger standards on fuel efficiency in cars. In terms of the behavioural dimensions, Brazilian's students were more financially driven (F=38.351; sig=0.000) overall. Belgian students showed greater propensity for consumption of eco-friendly products (F=7.745; sig=0.000) and household energy saving (F=273.939; sig=0.000). A possible explanation might be linked to the fact that the average age of participants was higher at the Belgian institution and that they may have lower expectations of third parties (75.6% of the Brazilian respondents were under 25 years old, while 57.6% of the Belgian respondents are in that age group). Moreover, the typical Belgian governance structures (federal versus regional level) will also not promote "belief in government". The third layer from the EU may increase the complexity still further and thus reduce the trust in the government as a third partner for the Belgian participants.

Table 6. Institutional differences

Dimension	Belgium		Brazil	
	Mean	SD	Mean	SD
Attitudinal dimensions				
Scientists' role	2.667	0.939	4.035	0.653
Citizens' role	2.178	0.790	3.026	0.852
Government's role	3.560	0.646	3.792	0.661
Behavioural dimensions				
Consumption of eco-friendly products	2.459	0.697	2.313	0.735
Financially driven behaviour	3.173	0.508	3.407	0.518
Household energy saving	2.922	0.731	1.984	0.817

Despite the scepticism illustrated by their attitudinal positions, the Belgian respondents scored quite highly on the behavioural dimensions. It is known that an individual's behaviour is not always consistent with their attitudes. Bael (2009) has previously shown that people exhibit varied behaviours in different contexts and under the influence of different external and internal factors and actions may or may not be consistent with their underlying attitudes. Sometimes an individual's behaviour is influenced less by their underlying attitudes than by the prevailing social norms. This could be an explanation for the Belgian behavioural dimensions being mostly higher than the Brazilian ones. There are significant current initiatives within the University (PXL) to include sustainability in their policies which may have had a positive influence on their students' behaviour in comparison with Brazilian students.

In addition, the World Values Survey (Halpern, 2005; Inglehart, 2014) indicates that, historically, Brazil has been among the nations with a low social capital level and a downward trend. Social capital can be understood as the systems of participation and reciprocity that involve community relations (Putnam, 1993). When social capital is less present, there is a tendency towards opportunism and selfish attitudes and behaviours since it implies that individuals can engage in the common good (Coleman, 1990; Inglehart, 2014). On the other hand, in Belgium, social capital levels are higher and tending to increase, showing a more communitarian spirit in attitudes and behaviours. However, further research would be needed to confirm this hypothesis. There are some interesting opportunities to explore the impact of personal, situational and behavioural variables on the relationship between attitudes and behaviour (Roberts *et al*., 2017). Analysing the cultural dimensions of both countries following the framework provided by Hofstede (2011) might also be informative in providing a better understanding of the differences between the countries and the ways in which they might influence individual behaviour. An analysis of the psychographics (e.g., lifestyles and values) would enrich future analysis.

5. Conclusions

This research involved deploying a widely used, rigorously tested energy literacy survey in two novel contexts, and using a new analytical approach. Three elements of sustainable attitudes and three elements of sustainable behaviours have been identified, and a linear regression analysis

used to develop an equation linking certain attitudes and behavioural dimensions to overall energy usage. This enhanced theoretical model of individual energy use offers an additional tool to explore energy literacy in future research and suggests that overall energy use is positively related to consumption of eco-friendly products and financially driven behaviour but negatively related to a strong belief in science, suggesting a possible over-optimism about the role of scientists in solving energy problems. This new insight emphasises the need for care to be taken in educational contexts to ensure that students understand that there is a role for individual action as well as scientific advance and government regulation in combating climate change. Differences between the two contexts also emerged, with Brazilian students being generally more optimistic about the role of scientists, citizens, and the government than those in Belgium. Perhaps reflecting students' different economic circumstances in the two countries, those in Brazil were more financially motivated, and the Belgian students showed a greater propensity for consumption of eco-friendly products and household energy saving.

It is not clear that in either context, the attitudes and behaviours of respondents are sufficient to drive the level of change needed to avert the climate crisis. Echoing previous research in the UK and Portuguese context, this study notes the limited sense of agency felt by students both in Belgium and Brazil regarding influencing the actions of government or businesses. These are sobering findings, given the clear need for strong political action globally. There is also evidence that, like most of the students surveyed worldwide, the behaviours which were most undertaken were not those that save the most energy! Students in Belgium and Brazil, as with those in the UK and Portugal, were more likely to see turning off lights and other similar activities as playing a pivotal role, despite their limited impact on energy use overall. Findings differed significantly from the Chinese context, leaving this as an outlier where students had hugely different attitudes and behaviours towards energy saving. Further research on cultural context, and the implications for energy saving and sustainability education would be extremely valuable.

This paper contributes to a broader debate on strategies for implementation of ESD and education for sustainability (EfS) by mapping arguments on competencies for SD and sustainability with a particular focus on higher education institutions. Our findings suggest that: (i) universities should focus on individual behavioural changes alongside teaching sustainability science (to reduce the risk that students rely on scientists to solve energy problems); (ii) governments should encourage public policies to raise awareness of the role of citizens in the sustainable use of energy; and (iii) universities should identify key elements for the construction of north-south cooperation proposals, such as capacity building programs for the dissemination of best sustainable practices. By identifying factors influencing students' perceptions of sustainability, and their energy saving activities, this study provides pertinent evidence for social researchers and university managers on ways in which the sustainable university ideal might be realised.

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Words 7903

Rebuttal Letter New revision dd 25/01

1) The authors still need to address comment #1 from my previous review 'Regarding Table 4, it is not clear why the superscript reference, d, appears at the bottom of this table (d Dependent Variable: A12 - When it comes to energy use, how would you describe yourself). The 'd' superscript itself is not attributed to anything in the table. The same superscript reference appears as 'a' at the bottom of Table 5 and, also, does not appear to be used in Table 5. Either place these superscript references appropriately or delete them.

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Economy driven behaviour	-0.234	0.059	-0.139	-3.953	0.000

2) The new paragraph on Page 6 ending 'Apart from the apparent benefits societies garner from university engagement, universities gain advantages too.' is a little vague. It will be helpful to add something here that explains (briefly) exactly what universities gain from such engagement.

Previous text

The quadruple helix approach illustrates the interaction with all stakeholders and the interdisciplinarity shows that EE projects incorporate economic benefits, as well as education, wellbeing, and community engagement.

New Text

Because all stakeholders (government, business, knowledge institutions and society) are involved in the quadruple helix model, it is logical that the Energy Efficiency projects are given a more holistic and ecosystemic approach. In this way, such projects contribute to the well-being of the user of the building (internal climate). Moreover, this building can be part of a healthy environment (external climate). By involving all these stakeholders, it

	becomes a co-creation process for the HEI in which professors, the business world and students work together on assignments and realizations. In addition, silos are broken down, and there is a shift from linear to circular thinking (Health (2021). It provides better (more supported) solutions and a gain for the participants; students and business get to know each other better with a view to further professional collaborations, apart from the monetary and environmental gain in the EE project itself.
1. Originality: Does the paper contain new and significant information adequate to justify publication?: Yes, the paper contains new work that adds to a body of existing research. 2. Relationship to Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?: The authors provide a well-defined context and demonstrate their understanding of the subject with an adequate range of citations. It appears no significant published work has been ignored. 3. Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed appropriate?: The methodology used by the authors is presented clearly and has been verified in other research. This forms a solid basis for the analytical work. 4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together the other elements of the paper?: The results are presented very well and are easy for the reader to access. These results are analysed, discussed and final conclusions are drawn that link in with these appropriately.	

5. Implications for research, practice and/or society: Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: The implications of this study are presented very well by the authors. Theory and practice are linked in an analytical approach that can be easily understood and used by other researchers or practitioners in the area of sustainability in higher education. Equally, their work can aid decision-makers in governmental and societal organisations. 6. Quality of Communication: Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc.: Apart from a few minor corrections (see below) the paper is well written in clear language that conveys the information to the reader. Overall, the IJSHE readership will find the paper engaging and a useful reference for similar research work.	
Reviewer 2 Recommendation: Accept Comments: Appreciate the attention to the comments and the revisions.	

Additional Questions: 1. Originality: Does the paper contain new and significant information adequate to justify publication?: Please see previous comments 2. Relationship to Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?: Please see previous comments. The revision strengthened the theoretical insights. 3. Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed appropriate?: Yes, agree and already strong in the earlier version. 4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together the other elements of the paper?: The added text in the revision helps to pull the analysis together a bit better. 5. Implications for research, practice and/or society: Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: I think is has some potential for others to build on. The results are promising for follow-up efforts in different locations.	

6. Quality of Communication: Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc.: Yes, very well written and expressed.	