Green but Misunderstood: Students' Perceptions of Renewable Energy Sources

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Declaration of interest statement

All authors have approved the manuscript and agree with its submission to ***Global NEST***.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Abstract

Renewable energy sources are increasingly occupying a larger space in the global energy mix, as a response to environmental degradation. Despite the growing focus of policy on energy transition and climate neutrality, the Greek education system has not aligned with this trend. This study detects students' knowledge and misconceptions regarding renewable energy sources with an emphasis on bioenergy. The empirical analysis carried out on a sample of 6,161 high school students demonstrated the determining factors that lead students to misconceptions related to the classification of energy sources as renewable or bioenergy sources. The results of the binary logistic regression applied reveal that misunderstandings are topic-related and linked to gender, self-assessed energy knowledge, conservation behaviour, and source of information. Importantly, increased perceived knowledge or environmental concern do not always translate into accurate understanding, particularly in relation to fossil fuels, suggesting information provided by formal or informal education sources in a way that lead students to erroneous perceptions and views. These results lead us to the conclusion that energy literacy needs to be strengthened through qualitative and quantitative improvements to the curriculum.

Keywords: renewable education; misconceptions; sociodemographic; students; Greece

1. Introduction

Our civilization relies on conventional forms of energy, even though their reserves are dwindling and the cost of their recovery is increasing over time (Arutyunov & Lisichkin, 2017; Lior, 2008). This, combined with the degradation of the environment from the use of fossil fuels, has led in recent decades to the development of energy transition strategies by states to forms of green energy (Zou *et al*., 2016). The sun, waterfalls, wind, geothermal energy, biomass, tides are forms of renewable energy sources, that is, they are resources whose reserves are renewed by nature at such rates that these resources are considered practically inexhaustible (Deshmukh *et al*., 2023). In the energy mix of renewable energy sources, bioenergy is a less popular source compared to solar and wind energy, as the 79,000 TWyr of solar energy received by our planet annually is the most easily accessible energy source that is capable of covering the existing primary energy demand many times over, just like wind energy but to a lesser extent (Perez & Perez, 2022). According to the Greek Ministry of Environment and Energy (M.E.E.), bioenergy is important for achieving climate neutrality and can be a cornerstone of Europe's energy transition, as 95% of biomass can be produced within the countries of the European Union. For this reason, in the revised national plan for energy and climate, renewable energy sources biomass is expected to be an important tool for achieving energy and climate goals for 2030 and by extension for the period up to 2050 (M.E.E., 2024). Biofuels such as bioethanol,

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biodiesel, biomethane, biohydrogen and biohythane, derived from biomass (Amjith & Bavanish, 2022) are intended to be an alternative to fossil fuels mainly in the machinery sector and mainly in transport. However, the European Court of Auditors (E.C.A.) considers that there is a lack of long-term perspective as a series of obstacles such as the lack of availability of biomass and cost inhibit the wider spread of the use of biofuels (E.C.A., 2023). Energy is directly linked to sustainability, especially renewable energy sources. Sustainable management of energy resources is a necessary prerequisite for addressing climate change, energy security, energy equality and autonomy, and ecological balance (Elkhatat & Al-Muhtaseb, 2024). Bioenergy is an efficient renewable energy source that can deliver significant environmental economic and social benefits, with a strong positive impact on all three pillars of sustainability (Yalini *et al.*, 2024). Today's students, as tomorrow's consumers, should have the necessary energy literacy to be able to make sustainable choices that support their well-being while preserving the environment for future generations (Casmana *et al*., 2023). Secondary school students' knowledge about renewable energy sources is presented by the research that has been carried out as limited as they do not possess basic knowledge while the information provided to them by formal and informal education is limited (DeWaters & Powers, 2011; Fah *et al*., 2012; Kaczmarczyk & Urych, 2022; Nuhanovic, 2021; Tortop, 2012; Yeh *et al*., 2017). This leads to the inability of students to distinguish between renewable and non-renewable energy sources (Çelikler & Aksan; 2015; Keramitsoglou, 2016; Zyadin, 2012).

Data on the knowledge of Greek students regarding renewable energy sources is scarce, while there are relatively few studies in the international literature that refer to the knowledge of secondary school students regarding bioenergy. This paper attempts to fill this gap. The primary aim of this study is to investigate the misconceptions among Greek secondary school students regarding renewable energy sources, with a particular emphasis on biofuels. The motivation is the minimal hours provided by the Greek educational system's timetable for renewable energy sources and the minimal and non-autonomous references that exist in school textbooks on bioenergy. The Greek educational system is centralized (Papazoglou & Koutouzis, 2022). Teachers follow the curriculum without any room for teaching flexibility (Alexopoulos *et al*., 2026; Kougias *et al*., 2023). The Greek curriculum has remained unchanged for the last twenty years. It has not been updated on renewable energy issues. In total, only 18 hours of teaching on renewable energy sources are available to primary and lower secondary school students. Students' lack of contact with knowledge about renewable energy sources and biofuels leads them to low energy literacy and misconceptions (De Waters *et al*., 2013; Białynicki-Birula *et al*., 2022). This fact highlights the need to modify the structure and content of the curriculum, enrich it with topics related to clean energy, and to adopt teaching practices that will promote energy education and empower future citizens to contribute to more sustainable societies (Bosch *et al*., 2025; Tassi *et al*., 2026).

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2. Materials and Methods

The survey was conducted in person using a structured questionnaire. The development and structure of the questionnaire was based on the exploration of the research questions as defined in the initial phase of the research design. The questionnaire was pilot tested on middle and high school students. The observations recorded in the pilot test and the conclusions drawn led to the revision of certain questionnaire items. Internal consistency of the questionnaire was good (Cronbach's α=.84). Stratified sampling was employed in the region of Attica, which is divided into seven secondary education directorates. In each of the 50 junior high schools surveyed, after permission from the school principal, sampling took place during science class in the presence of the class teacher, resulting in a sample of 6,161 students. Table 1 shows the questions, the coding and the descriptive statistics (mean and standard deviation) for each of the key variables analysed in the present study.

Table 1. Descriptive statistics of variables included in the empirical models

Questions	**Variable**	**Coding**	**Mean**	**Std. Dev**	**Min**	**Max**
Gender	gender	1=male 0=female	0.509	0.500	0	1
How much do you feel you know about energy?	know	1=Nothing 5=A lot – expert	3,115	0.816	1	5
When it comes to energy use, how would you describe yourself?	consume	1=High energy user 5= I almost always try to save energy	3,107	0.980	1	5
The one thing that has contributed most to your understanding of energy issues and problems is school	school	1=Yes 0=No	0.381	0.486	0	1
The one thing that has contributed most to your understanding of energy issues and problems is internet	internet	1=Yes 0=No	0.258	0.438	0	1
How often do you talk to your family about ways you can save energy in and around your home?	discuss	1= Not at all 5= A lot	3,361	1,088	1	5
Which of the following energy sources is NOT renewable?						
Solar	thesun	1=Yes 0=No	0.618	0.241	0	1
Coal	coal	1=Yes 0=No	0.592	0.492	0	1
Biomas (wood, waste, plants, alcohol fuels)	biomass	1=Yes 0=No	0.164	0.370	0	1
Water (hydro) power	hydroele	1=Yes 0=No	0.089	0.285	0	1

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Geothermal	geothermal	1=Yes 0=No	0.093	0.291	0	1
Which of the following choices in not a biofuel?						
Ethanol	ethanol	1=Yes 0=No	0.202	0.401	0	1
Diesel fuel made from vegetable oil	vegdiesl	1=Yes 0=No	0.114	0.318	0	1
Vegetable oil	vegioil	1=Yes 0=No	0.167	0.373	0	1
Gasoline	gasoline	1=Yes 0=No	0.268	0.443	0	1
Methane captured from cow manure	methcow	1=Yes 0=No	0.249	0.432	0	1

3. Results

3.1 Statistical analysis

Students were given five options to identify which of these is non-renewable. More than half indicated coal as a non-renewable energy source, followed by biomass (16.39%), geothermal (9.33%), water (8.93) and solar (6.17%) (figure 1)

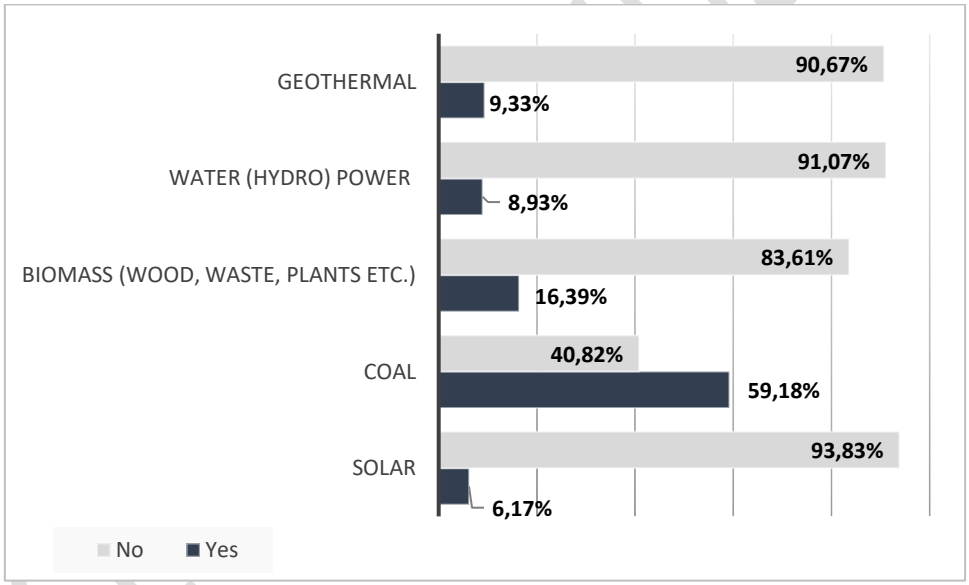


Figure 1. Students' responses about the energy source they consider non-renewable

Figure 2 depicts the students' choice of the fuel they do not consider to be a biofuel. There was no choice that stood out quantitatively with Gasoline being the first choice (26.85%) followed by methane captured from decaying cow manure (24.9%) and ethanol (20.18%). Diesel from vegetable oils (11.38%) and vegetable oils (16.7%) were indicated by the students to a lesser extent as non-biofuels.

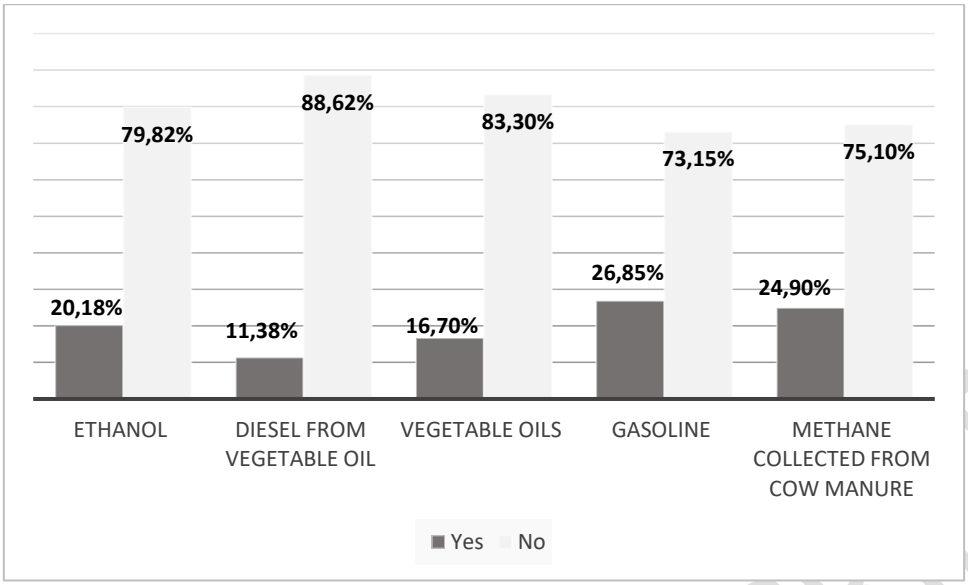


Figure 2. Students' responses about the fuel they believe is not biofuel

Table 2 presents the results of the Chi-square tests conducted to examine the associations between the misconceptions towards renewables and the students' sociodemographic variables used in the study.

Table 2. Chi-square test of significance of associations between variables

Variables		Pearson chi2	p-value
thesun	gender	6,205	0.013**
biomass	gender	7,305	0.007**
coal	gender	8,004	0.005**
hydroele	gender	6,282	0.012**
geothermal	gender	0.891	0.345
thesun	know	18,758	0.001**
biomass	know	0.8416	0.933
coal	know	32,716	0.000***
hydroele	know	19,579	0.001**
geothermal	know	16,457	0.002**
thesun	consume	27,280	0.000***
biomass	consume	3,473	0.482
coal	consume	27,567	0.000***
hydroele	consume	16,832	0.002**
geothermal	consume	1,251	0.870
thesun	school	0.005	0.945
biomass	school	0.064	0.800
coal	school	0.000	0.989
hydroele	school	0.023	0.879
geothermal	school	0.1919	0.661
thesun	internet	0.982	0.322
biomass	internet	1,042	0.307
coal	internet	10,558	0.001**
hydroele	internet	4,647	0.031**

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geothermal	internet	1,584	0.208
thesun	discuss	16,407	0.003**
biomass	discuss	0.790	0.940
coal	discuss	4,522	0.340
hydroele	discuss	5,982	0.201
geothermal	discuss	0.429	0.980
ethanol	gender	6,812	0.009**
vegdiesl	gender	0.237	0.626
vegioil	gender	0.781	0.377
gasoline	gender	0.049	0.826
methcow	gender	5,033	0.025**
ethanol	know	4,095	0.393
vegdiesl	know	21,060	0.000***
vegioil	know	8,323	0.080*
gasoline	know	15,509	0.004**
methcow	know	4,429	0.351
ethanol	consume	8,427	0.077
vegdiesl	consume	12,709	0.013**
vegioil	consume	9,081	0.059
gasoline	consume	19,946	0.001**
methcow	consume	7,022	0.135
ethanol	school	0.528	0.468
vegdiesl	school	2,681	0.102
vegioil	school	1,488	0.222
gasoline	school	0.044	0.834
methcow	school	1,080	0.299
ethanol	internet	2,502	0.114
vegdiesl	internet	0.125	0.723
vegioil	internet	5,440	0.020**
gasoline	internet	0.136	0.713
methcow	internet	0.009	0.926
ethanol	discuss	1,660	0.798
vegdiesl	discuss	7,528	0.111
vegioil	discuss	4,782	0.310
gasoline	discuss	1,860	0.762
methcow	discuss	0.574	0.966

Note: *** and ** represent levels of significance at 1%, 5% and 10% respectively

The chi-square analysis for gender reveals statistically significant associations with four out of five energy sources. Specifically, significant gender differences were observed for solar ($p = 0.013$), biomass ($p = 0.007$), coal ($p = 0.005$), and hydropower ($p = 0.012$). This suggests that male and female students differ substantially in their understanding of which sources are renewable, with these

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differences especially pronounced in more ambiguous or less discussed sources such as biomass and coal. No gender difference was found for geothermal energy ($p = 0.345$), indicating a possible general lack of familiarity across both genders with this energy form. This is supported by the fact that in school textbooks renewable energy sources occupy very little space, while biomass and geothermal energy are mentioned only briefly. This is a paradox as in Greece there is a volcanic zone that is active in some parts and geothermal fields under research such as that of the island of Milos.

As for self-reported energy knowledge (know), there is a strong and consistent association with misconceptions for most sources. Statistically significant results were found for solar ($p = 0.001$), coal ($p < 0.001$), hydropower ($p = 0.001$), and geothermal ($p = 0.002$), meaning that students who rated themselves as more knowledgeable tended to answer these questions more correctly. The exception was biomass ($p = 0.933$), suggesting that even students who believe they know more about energy struggle to classify biomass correctly—a finding aligned with the literature pointing to poor awareness of bioenergy. This is due to the fact that students do not have daily contact with biomass production facilities, unlike solar and wind energy, where students have visual contact with solar mirrors and wind turbines, leading them to investigate the subject.

Regarding energy-saving behavior (consume), significant associations emerged for solar ($p < 0.001$), coal ($p < 0.001$), and hydropower ($p = 0.002$). This implies that students who report engaging in energy-saving behavior are less likely to hold misconceptions about these sources. Again, biomass ($p = 0.482$) and geothermal ($p = 0.870$) were not significant, reinforcing the notion that more obscure sources elicit confusion regardless of behavior.

The variable school—as a formal source of renewable energy knowledge—did not yield any statistically significant associations across all five energy sources, with all p-values well above 0.05. This points to the limited impact of formal schooling in shaping accurate beliefs about renewables, confirming gaps previously identified in the literature and in Greek curricula. Students come into contact with renewable energy sources when they work on a related task assigned to them by their science teachers. However, this is not planned by the school curriculum but is based on the opportunistic interest that may arise during teaching or during the implementation of an environmental program, which is usually developed in collaboration with organizations outside formal education. In contrast, the internet was significantly associated with fewer misconceptions about coal ($p = 0.001$) and hydropower ($p = 0.031$), but not for solar, biomass, or geothermal. This suggests that informal online learning may help clarify some—but not all—energy topics. Finally, the frequency with which students discuss energy-saving practices with their families was significantly associated only with solar ($p = 0.003$). This underscores the influence of the family environment in

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shaping understanding of mainstream renewable energy sources. However, for other sources, especially less familiar ones, discussion alone may not be enough to counteract misinformation.

The analysis of biofuel-related misconceptions reveals fewer but still meaningful patterns. Starting with gender, significant associations were found for ethanol ($p = 0.009$) and methane from cow manure ($p = 0.025$). This mirrors the renewable energy findings, suggesting that gender-based differences in knowledge extend to certain biofuels. However, no significant gender effects were found for diesel from vegetable oil, vegetable oil itself, or gasoline.

Concerning self-reported knowledge, significant associations were found for diesel from vegetable oil ($p < 0.001$), vegetable oil ($p = 0.080$), and gasoline ($p = 0.004$). These results align with expectations: students who report higher energy knowledge tend to better classify alternative fuels—although the significance for vegetable oil is marginal ($p < 0.10$). Interestingly, no such association was found for ethanol ($p = 0.393$) or methane ($p = 0.351$), indicating possible conceptual confusion or lack of familiarity with those particular fuels.

Energy-saving behavior (consume) was significantly associated with correct classification of diesel from vegetable oil ($p = 0.013$) and gasoline ($p = 0.001$), and marginally with vegetable oil ($p = 0.059$). This indicates that behavioral engagement with sustainability may positively influence students' ability to identify bio-based fuels—though again, this does not hold uniformly across all fuel types. In contrast to the renewable energy section, school education again failed to show any significant association across all five biofuel misconceptions, reinforcing the earlier concern that current educational content does not effectively convey bioenergy concepts. The subject of biofuels is absent from the already lacking and fragmented energy education in Greece, as most of the school textbooks are over twenty years old, without the environmental awareness and the shift towards renewable energy sources that has been observed in recent years. As a result, there is no significant reference to biofuels that provides students with satisfactory information about them.

The internet showed a significant association only for vegetable oil ($p = 0.020$), implying that some biofuels may be better understood by students who use online sources, but that this effect is not widespread across all biofuel types. Finally, discussion with family (discuss) was not significantly associated with biofuel knowledge in any model. This suggests that biofuels may not be commonly discussed in household settings, even among families that engage in general energy-saving conversations.

3.2 Binary logistic regression analysis

The investigation of the factors affecting students' choice y_i on which energy source is renewable or in which fuel is biofuel was assessed applying the following logistic regression equation

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$$yi = bo + b1gender + b2know + b3consume + b4school + b5internet + b6discuss + \varepsilon i$$

where ε_i are the residuals or errors of the equation.

We will apply binary logistic regression analysis to determine the effect of demographic data (variables: gender, know, consume, school, internet, discuss) on students' choice concerning a) the non-renewable energy source (dummy variables: thesun, coal, biomass, hydroele, geothermal) and b) the non-biofuel fuel (dummy variables: ethanol, vegdiesl, vegioil, gasoline, methcow). The variables used in the analysis and their interpretation (coding and meaning) are presented in table 3 below. Tables 4 and 5 presents the econometric estimation of the specific models.

Table 3. Binary logistic regression variables' interpretation

Questions	**Variable**	**Coding**
Gender	gender	1=male 0=female
How much do you feel you know about energy?	know	1=Nothing 5=A lot – expert
When it comes to energy use, how would you describe yourself ?	consume	1=High energy user 5= I almost always try to save energy
The one thing that has contributed most to your understanding of energy issues and problems is school	school	1=yes 0=No
The one thing that has contributed most to your understanding of energy issues and problems is internet	internet	1=yes 0=No
How often do you talk to your family about ways you can save energy in and around your home?	discuss	1= Not at all 5= A lot
Which of the following energy sources is NOT renewable?		
Solar	thesun	1=yes 0=No
Coal	coal	1=yes 0=No
Biomas (wood, waste, plants, alcohol fuels)	biomass	1=yes 0=No
Water (hydro) power	hydroele	1=yes 0=No
Geothermal	geothermal	1=yes 0=No
Which of the following choices in not a biofuel?		
Ethanol		1=yes 0=No
Diesel	vegdiesl	1=yes 0=No
Vegetable	vegioil	1=yes 0=No
Gasoline	gasoline	1=yes 0=No
Methane	methcow	1=yes 0=No

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Table 4. Binary logistic regression models: Determinants of students' misconception toward renewable energy sources

Independent variables	Model I			Model II			Model III			Model IV			Model V		
	Sun			Coal			Biomass			Water (hydro) power			Geothermal		
	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1
Constant	-1.948*** (-6.58)	–	–	-0.764*** (-5.08)	–	–	-1.237*** (-6.29)	–	–	-1.040*** (-4.21)	–	–	-1.547*** (-6.30)	–	–
gender	0.239** (2,19)	1.270	0.270	0.166** (3.13)	1.182	0.182	-0.205** (-2.91)	0.815	-0.185	-0.246** (-2.68)	0.782	-0.218	-0.069 (-0.77)	0.934	-0.066
know	-0.115* (-1.77)	0.891	-0.109	0.156*** (4.79)	1.169	0.169	-0.001 (-0.03)	0.999	-0.001	-0.179** (-3.25)	0.836	-0.164	-0.182** (-3.37)	0.833	-0.167
consume	-0.212*** (-3.85)	0.809	-0.191	0.141*** (5.17)	1.151	0.151	-0.052 (-1.45)	0.949	-0.051	-0.161** (-3.44)	0.852	-0.148	-0.012 (-0.27)	0.988	-0.012
school	-0.078 (-0.64)	0.925	-0.075	0.137** (2.26)	1.146	0.146	-0.040 (-0.50)	0.961	-0.039	-0.132 (-1.30)	0.876	-0.124	-0.128 (-1.27)	0.879	-0.121
internet	-0.169 (-1.22)	0.844	-0.156	0.261*** (3.85)	1.298	0.298	-0.098 (-1.10)	0.906	-0.094	-0.289** (-2.43)	0.749	-0.251	-0.188 (-1.65)	0.828	-0.172
discuss	0.049 (0.97)	1.050	0.050	0.003 (0.11)	1.003	0.003	-0.025 (-0.78)	0.975	-0.025	-0.001 (-0.04)	0.999	-0.001	-0.000 (-0.00)	1.000	0.000
Log likelihood	-1413.487			-4127.573			-2742.911			-1835.158			-1903.101		
Pseudo R^2	0.192			0.192			0.210			0.199			0.141		

Note: ***, ** and * represent levels of significance at 1%, 5% and 10% respectively

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Table 5. Binary logistic regression models: Determinants of students' misconceptions about biofuels

Independent variables	Model I			Model II			Model III			Model IV			Model V		
	Ethanol			vegdiesl			vegioil			Gasoline			methcow		
	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1	Estimated coefficients	Odds ratio	$e^{\beta i}$ -1
Constant	-1.682*** (-9.10)	–	–	-1.111*** (-4.79)	–	–	-1.251*** (-6.41)	–	–	-1.572*** (-9.35)	–	–	-1.049*** (-6.17)	–	–
gender	0.164** (2.51)	1.178	0.178	0.014 (0.17)	1.014	0.014	-0.061 (-0.88)	0.941	-0.059	0.008 (0.14)	1.008	0.008	-0.112* (-1.87)	0.894	-0.106
know	0.037 (0.93)	1.038	0.038	-0.151** (-3.04)	0.860	-0.140	-0.045 (-1.06)	0.956	-0.044	0.135*** (3.72)	1.145	0.145	-0.056 (-1.52)	0.946	-0.054
consume	-0.027 (-0.81)	0.973	-0.027	-0.065 (-1.54)	0.938	-0.062	-0.066* (-1.84)	0.936	-0.064	0.080** (2.67)	1.084	0.084	0.023 (0.76)	1.024	0.024
school	0.015 (0.20)	1.015	0.015	-0.178* (-1.90)	0.837	-0.163	0.002 (0.03)	1.002	0.002	0.009 (0.14)	1.009	0.009	0.073 (1.06)	1.076	0.076
internet	0.119 (1.46)	1.127	0.127	-0.064 (-0.65)	0.936	-0.064	-0.183** (-2.02)	0.833	-0.167	0.024 (0.32)	1.024	0.024	0.041 (0.54)	1.042	0.042
discuss	0.045 (1.48)	1.046	0.046	-0.062 (-1.64)	0.940	-0.060	0.019 (0.57)	1.019	0.019	-0.035 (-1.29)	0.965	-0.035	0.019 (0.66)	1.019	0.019
Log likelihood	-3091.415			-2172.425			-2773.922			-3572.879			-3453.115		
Pseudo R^2	0.121			0.149			0.120			0.131			0.113		

Note: ***, ** and * represent levels of significance at 1%, 5% and 10% respectively

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The study explored the factors associated with misconceptions about renewable energy sources and biofuels among Greek secondary school students using ten binary logistic regression models. Each of the first five models assessed the likelihood that a student incorrectly believes a specific renewable energy source is not renewable, with the binary outcome (1 = misconception) as the dependent variable.

Considering the question "Sun is not renewable" (Model I), three variables significantly predicted misconceptions. Gender was a strong predictor, with male students being 27% more likely than female students to mistakenly believe that solar energy is not renewable (OR = 1.270, $p < 0.05$). Additionally, students who rated their energy knowledge higher were less likely to hold this misconception (OR = 0.891, $p < 0.10$), indicating that even self-assessed knowledge has a protective effect in this context. Likewise, students who reported greater energy-saving behavior also had lower odds of making this error (OR = 0.809, $p < 0.001$). This model supports the idea that both cognitive engagement and sustainable behavior are linked with more accurate energy beliefs, although the gender gap suggests uneven exposure to reliable information. The analysis of the results related the statement "Coal is not renewable" (Model II) revealed counterintuitive findings. Male students again had a higher probability of error (OR = 1.182, $p < 0.01$), but more surprisingly, students with greater energy knowledge (OR = 1.169, $p < 0.001$) and those reporting energy-saving behaviors (OR = 1.151, $p < 0.001$) were more likely to misclassify coal as a renewable source. Furthermore, students who cited school as a major learning source were more prone to error (OR = 1.146, $p < 0.05$), as were those relying on the internet (OR = 1.298, $p < 0.001$). These results suggest the existence of widespread confusion, possibly due to misinformation, challenging the assumption that environmental engagement automatically translates to accurate energy knowledge (Pothitou *et al.*, 2016). Only gender was statistically significant for the misconception "Biomass is not renewable" (Model III). Males were less likely to hold this misconception than females (OR = 0.815, $p < 0.01$). No other variables—including self-assessed knowledge, behavior, or information sources—were significant. This may reflect greater male exposure STEM and technical contexts involving biomass, which are more commonly addressed in vocational or science-technology domains (European Commission, 2021; Pagkratidou et al., 2025).

A combination of demographic, cognitive, and behavioural predictors revealed for "Hydropower is not renewable" (Model IV). Male students had lower odds of error (OR = 0.782, $p < 0.01$), as did those with higher self-assessed knowledge (OR = 0.836, $p < 0.01$) and greater conservation behavior (OR = 0.852, $p < 0.01$). Additionally, reliance on the internet was associated with fewer misconceptions (OR = 0.749, $p < 0.05$), indicating that online content, in this case, may provide accurate representations of hydropower as a renewable source. This model suggests that hydropower

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is better understood and less controversial, particularly when supported by both internal motivation and external digital resources.

Considering the statement "Geothermal is not renewable" (Model V), the only significant predictors were self-assessed knowledge (OR = 0.833, $p < 0.01$) and consume (OR = 0.988, $p < 0.01$), both associated with reduced odds of error. Neither gender nor information sources were significant in this case, emphasizing the role of internal cognitive and behavioural dispositions in shaping accurate understanding of less commonly discussed renewables such as geothermal energy. Taken together, the findings from these binary logistics regressions confirm that energy misconceptions are highly topic-specific, and that more self-assessed knowledge or behaviourally pro-environmental attitudes do not always reduce errors. The most striking evidence comes from the coal model, where better-informed and more eco-conscious students were actually more likely to misclassify it as renewable.

The second part of the study focused on analysing student misconceptions about biofuels, again using five separate binary logistic regression models. Only gender is statistically significant in case of "Ethanol is not a biofuel" (Model I). Male students being 18% more likely to wrongly identify ethanol as non-bio-based (OR = 1.178, $p < 0.01$). Despite ethanol's widespread use as a blended fuel, this finding suggests that students may lack clear exposure to how ethanol is derived and used, or may confuse it with synthetic chemical products. In contrast, energy self-reported knowledge had strong predictive protective effect for students for students who believe that "Diesel from vegetable oil (vegdiesl) is not a biofuel" (Model II) (OR = 0.860, $p < 0.01$), as did school-based learning, albeit to a lesser extent (OR = 0.837, $p < 0.10$). This model supports the value of both cognitive readiness and formal education when students are exposed to accurate curricular content about newer renewable fuel technologies. Furthermore, in the view that Vegetable oil is not a biofuel (Model III), two significant predictors emerged. Students with more energy-saving behavior had reduced odds of error (OR = 0.936, $p < 0.10$), as did those using the internet as a source of information (OR = 0.833, $p < 0.05$). These results imply that informal learning and pro-environmental habits can play a key role in correctly identifying lesser-known renewable fuel types.

Surprisingly, higher energy self-reported knowledge (OR = 1.145, $p < 0.001$) and energy-saving behavior (OR = 1.084, $p < 0.01$) were both associated with increased misconception regarding the fact that gasoline is not a biofuel (Model IV). This demonstrates a clear case of overgeneralization, where partial knowledge leads to incorrect categorical conclusions. In addition, male students were less likely to hold the misconceptions that "Methane from cow manure is not a biofuel" (Model V) (OR = 0.894, $p < 0.10$), potentially reflecting greater exposure to agricultural or waste-to-energy topics often featured in technical or vocational education paths.

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4. Discussion

The findings of the binary logistic regression models provide valuable information concerning the determinants of misperceptions in society regarding renewable energy and biofuels. The analysis shows that misconceptions are not evenly spread among the population, but that they differ according to sex, self-perceived knowledge, energetic behaviours or sources of information trusted by individuals. The direction of these effects is also inconsistent, which casting doubt on naïve conceptions of energy literacy and emphasizes the nuanced character of public understanding.

Gender is found to be a meaningful predictor in a number of the models, though the direction of this effect is not consistent across types of energy which is which is consistent with research showing differences in knowledge by gender (Arachchi & Managi, 2021; Lee, 2016). For solar and coal, male participants were substantially more likely to answer the questions about renewables knowledge incorrectly (Models I and II). This suggests that some participants may have lacked basic energy literacy in these fundamental components and could have been overconfident. Similarly, in models of biomass, hydropower, and methane from cow manure (Models III, IV, V) men made fewer errors, indicating more familiarity with less mainstream or technically presented sources.

This inconsistency implies that sex-based differences might be mediated by differences in exposure to certain energy discourses, rather than by overall energy literacy. Men, for instance, might have greater familiarity with biomass and methane in the context of industry, agriculture or engineering, and women might be better at recognizing the widely discussed clean technologies like solar power. The gender specific heterogeneities suggest that applied energy education also needs to address that some groups tend to be more prejudiced by specific types of misconceptions.

Energy self-assessed knowledge also washed out as a significant predictor variable frequently. Studies suggest the effect of self-assessment of knowledge on the individual's cognitive framework and mainly on energy issues (DeWaters & Powers, 2011; Sitzmann *et al*., 2010). Higher self-rated knowledge was related to fewer misconceptions for solar energy, hydropower, biofuels and geothermal energy, representing the perspective that higher self-reported knowledge supports correct beliefs. This is consistent with studies indicating that students who perceive their knowledge of energy issues to be high, are actually more likely to answer certain questions correctly (Cotton *et al.*, 2016). On the contrary, students with higher self-assessed knowledge are more likely to have misconceptions about coal and gas — a counterintuitive finding. This paradox highlights the constraints of self-reported knowledge, with people who perceive themselves as well informed falling prey to oversimplified or misguided narratives as also highlighted by studies that analyse misconceptions about charcoal (Mwampamba et al., 2013). These results highlight the need to distinguish between ‘facts as specified by science’ and ‘facts as perceived by the learner’ and for energy education not only to correct common misconceptions, but also to enhance general knowledge.

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Energy-saving behavior was another essential variable that generally operated as anticipated – it was less likely for energy-saving individuals to make mistakes about whether solar, hydropower, and geothermal energy are renewable. This implies that 'green' habits might represent or support greater environmental knowledge which is in line with previous studies (Liu & Tobias, 2024; Pothitou *et al.*, 2016). However, this relationship was not consistent across all energy sources. In coal and gasoline models, consistent with self-interested, energy conservers were even more likely to be misinformed. This (again) suggests overgeneralization or semantic confusion; environmentally active individuals might believe all "clean" fuels (or blends) to be renewable/bio-based despite the lack of clarity in energy typologies. These results suggest the importance of further elucidating the language and core conceptual differences between sustainability terms.

Unexpectedly, use of school and the internet for knowledge did not uniformly reduce misconceptions. In some models (especially when combining coal and gasoline), the utilization of these sources was positively associated with error, as it suggested an erroneous (misinformation or misinterpretation). In still others, including hydropower and vegetable oil, use of the internet decreased misconceptions. This finding implies that the effectiveness and accuracy of information sources are not all equal, and that people might not critically think to assess the credibility of information they have received. Especially in the digital space, where the subject of energy can be highly politicized or oversimplified, quality and clarity of information can be paramount. Such findings suggest potential benefits of enhancing formal environmental education curricula and of producing digitally accessible, scientifically accurate public-facing content.

The variation in predictors among models also accentuates the context-specific nature of energy misunderstandings. Well-known renewables like solar and hydropower were far more likely to be correctly identified by respondents, but there was more confusion when it came to sources like coal, biomass and methane, a result that appears in previous studies (Çelikler & Aksan 2015; Karatepe *et al*., 2012; Keramitsoglou, 2016; Tortop, 2012; Zyadin, 2012).

Misconceptions regarding biofuels such as ethanol or biodiesel were also less widespread than those for gasoline or methane, indicating differences in public acquaintanceship. This also reveals that energy literacy is not unidimensional, but fragmented: one can have correct knowledge in one domain and incorrect beliefs in another. This highlights the need for tailored, content-specific interventions, such as fact sheets, campaigns, or interactive tools that target areas of confusion identified.

5. Conclusions

Predictors of students' misconceptions about renewable energy sources and biofuels were examined in this study employing binary logistic models. The results show that energy misconceptions are common, presenting substantial variation across energy-related topics depending on the energy source

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and demographic subgroup. Importantly, the findings reveal that misconceptions are not arbitrary, but contingent upon a complex interaction among demographic characteristics, self-reported knowledge, energy-related behaviours, and information sources.

The findings made suggestions about gender, but the disparities were so frequent and contradictory that they were hard to parse: Males, for instance, were more likely to misidentify widely known renewables such as solar and ethanol, but less likely to misclassification more obscure options like biomass and methane. This is an indication that gender differences in exposure to energy or in interest may possibly affect topical knowledge. Self-rated knowledge and energy-saving behavior were generally protective against misinformation in the models on solar, hydropower and geothermal energy. Paradoxically, however, they were also related to increased misunderstanding when they related to coal and gasoline—suggesting possible over-confidence or confusion with fuel-related terminology.

Information sources were also mixed. There was some benefit of internet use in certain models (e.g., identifying hydropower or veggie oil as renewables) but also seen in some models with (e.g., coal, gasoline) in which both internet and school were linked to higher error rates. These results indicate that it is insufficient to allow access to information, at least when this is too rudimentary, simplistic or politicized and misunderstood.

Overall, these results emphasize the importance of designing content-focused educational interventions to increase not merely awareness, but also address underlying misconceptions. The difference between renewable and non-renewable resources must be communicated in educational literature, public campaigns and school curricula and notions about biofuels should be adjusted. And people need to be taught critical thinking and media literacy skills to help them untangle complicated or deceptive energy stories. These deficiencies need to be addressed for citizens to become informed and engaged in transitions to sustainable energy.

The findings of the present study have several practical implications. First of all, it is necessary that public campaigns move beyond more general awareness-raising and address confrontationally sustained misperceptions with more targeted and context-specific interventions. It is not enough to just advocate for renewable energy; students need the honest and sophisticated knowledge. Second, energy literacy curriculum should directly address misleading language as a barrier to better understanding, such as the frequent confusion of use of the terms “clean” and “renewable” energy and the confusion that exists around fossil, renewable, and bio-based fuel types. Further, the results lend support for the customization of communication strategies for audiences based on gender and behavioural profile which could increase the educational effectiveness in locales where topic

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familiarity and the distribution of misunderstanding differ substantially among groups. Curriculum developers and policy makers should also appraise the information that is produced and presented in formal (school curricula and textbooks) and informal (media and internet) channels and carefully prevent students from being faced with uncertain and conflicting information. Lastly, the research highlights the importance of cross-disciplinary research to elucidate the wider societal, psychological and ideological causes of energy misconceptions. These mechanisms are key to creating more efficient, heterogeneous and prospectivity energy education policies.

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