Empowering Future Energy Citizens: How Knowledge, Environmental Attitudes, and Student Characteristics Shape Perceptions of Renewables?

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Abstract

This study investigates the knowledge, attitudes, and willingness to support renewable energy among over 6,000 Greek lower secondary students, providing a comprehensive, data-driven exploration of factors influencing youth support for renewable energy initiatives The study aims to analyse overall opinions on renewables based on perceived and objective knowledge, pro-environmental attitudes, and important socio-demographic variables. Regression analyses indicate that people who hold pro-environmental attitudes are the most consistent and strongest supporters of these systems. However, knowledge has complex effects, increasing general support but at times decreasing support for local trade-offs. The results confirm the crucial role of pro-environmental attitudes in fostering youth support for renewable energy, while highlighting important gaps in objective knowledge, especially around bioenergy and national energy specifics. These findings highlight the importance of special environmental education efforts that focus on addressing the knowledge-attitude gap and fostering informed and committed support for renewable energy policies by young people, vital not only for Greece but also all of Europe in its quest for green energy.

Keywords: Renewable energy knowledge; environmental education; middle school students; statistical analysis; sustainability; Greece.

JEL Classification: I25; C10; C83; D83; Q42; Q56

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1. Introduction

Sustainability and renewable natural resources are often considered related terms as both bear the characteristic of continuous provision of goods without time limitations. The shift to renewable energy is a cornerstone of the European Green Deal and a shared priority across EU member states striving for sustainable development. However, climate and energy goals can be reached not only on technological innovation and political commitment but also on establishing an informed and supportive public (Triantafyllidou et al., 2024). Adolescents represent a key demographic target group, as future consumers, voters, and professionals, their knowledge and attitudes today will determine Europe's energy landscape of tomorrow.

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Prior researchers have documented low levels of objective knowledge about renewable energy sources (RES) among students. Turkish high school students (Tortop, 2012) and school students from Jordan (Zyadin, 2012) present minimal knowledge on RES, although generally they have positive attitudes toward environmental protection. This awareness – understanding discrepancy can undermine informed support for renewable policies, particularly when adoption has trade-offs, such as higher costs or local environmental impacts (Pascaris et al., 2021). Furthermore, previous studies on students in Turkey (Karatepe et al., 2012) and in Greece (Keramitsoglou, 2016) suggest factors such as gender, age, and family engagement may affect students' environmental attitudes and knowledge. Nevertheless, studies connecting these factors with willingness to support renewables remain scarce, especially in Greece. More specifically, two surveys of secondary school students in Greece have focused on RES, confirming the limited knowledge of students, especially on issues related to biomass, while at the same time highlighting the need for curriculum changes to promote RES (Kapassa et al., 2013; Keramitsoglou, 2016). Though research conducted across Europe and neighbouring regions have highlighted gaps in students' factual knowledge about RES and a disconnect between positive environmental attitudes and actual willingness to support RES policies, extended evidence-based explanations that consider both knowledge attitude, and willingness remain few. Interdisciplinary perspectives such as these are necessary to inform educational strategies and policies for public engagement that can contribute to meeting both environmental and societal goals.

This gap in knowledge is challenged in the study by conducting a multidimensional analysis of Greek middle school students' knowledge, environmental attitudes, and perception of renewable energy. The purpose of this study is to provide a holistic examination of the knowledge, attitudes, and perceptions of renewable energy among Greek middle-school students, and to determine the major drivers of their support that can inform an effective design of energy education and public engagement programmes. Using a large, representative sample of 6161 students, it analyses the associations between demographic factors, self-perceived and objective knowledge, pro-environmental beliefs and their support of renewables projects under economic or ecological trade-offs. By applying advanced statistical techniques this research contributes robust, policy-relevant evidence to support interdisciplinary efforts in education, environmental policy, and sustainable development across Europe. More precisely, the objectives of the research are the following:

- Analyse students perceived and factual knowledge about renewable energy.
- Examine how students' pro-environmental attitudes affect factual knowledge about renewable energy.
- Analyse how knowledge, pro-environmental attitudes, and demographic influences predict perceptions of renewable energy.

The findings of this study aim to inform energy education stakeholders designing effective energy education programs, helping to align students' positive attitudes with accurate knowledge and realistic expectations. Unlike previous studies that treat knowledge or attitudes towards renewables in isolation, the present study integrates objective knowledge with perceived knowledge, multidimensional environmental attitudes towards renewables. Thus, it makes a substantial contribution to interdisciplinary insights into the knowledge-attitudes-behavior connection in relation to renewables support among young people. Fostering well-informed and active youth citizens is essential factor for achieving a sustainable energy future and fulfilling Greece's and Europe's renewable energy targets.

2. Literature Review

Education towards renewable energy. The educational process is the one that will create the necessary attitudes, perceptions and behaviours of a society towards RES by enriching the ecological skills of the whole that researchers call human capital. Pro-environmental attitudes and behavior are considered socially acceptable and correct, despite the fact that in many cases they can lead to higher financial costs, can be time-consuming or less enjoyable. For this reason, the adoption of environmentally sustainable behaviors in every context of human activity is important (Popescu, 2019). The skills that make up human capital, a subset of which is called green human capital (GHC), include those that refer to an individual's environmental knowledge and skills, understanding of sustainability principles, and sustainable behaviours and attitudes (Crifo, 2024; Shoaib et al., 2021). Formal education is the starting point for the formation of environmentally sensitive individuals who will continue outside of education, through a learning society, to shape opinions and behaviors that will follow them into their adult lives, fostering the twin transition, green and digital, which is a necessity for socio-economic development (Popescu, 2011; Popescu & Stam, 2024).

RES are a relatively new subject related to energy as in the last decade their use began to spread at a high rate on a global scale. Nevertheless, there are several studies that refer to RES, mainly to the factors that influence young people's attitudes and beliefs about them.

Knowledge and attitudes about renewable energy and their determinant factors

Students have shown a low level of knowledge about RES (Tortop, 2012; Yeh et al., 2017), as they lack information and basic knowledge about RES technology, stating that they have limited awareness of RES in general (Keramitsoglou, 2016; Nuhanovic, 2021). According to Kaczmarczyk & Urych (2022), Polish secondary school students assess their level of knowledge as "adequate". They are familiar with the term "renewable energy sources", but only 13% of students responded positively about the use of renewable energy technologies in schools (Ntanos & Kyriakopoulos, 2018). Students in Jordan (Zyadin et al., 2012), in Greece (Keramitsoglou, 2016) and in Turkey (Çelikler & Aksan, 2015) have limited ability to distinguish between renewable and non-RES, possibly due to the complexity of new energy technologies. Some students incorrectly reported that non-RES, such as oil, fossil fuels, coal, natural gas and radioactive elements, are renewable sources (Çelikler & Aksan, 2015; Zyadin et al., 2012). Although many students are familiar with common RES, such as solar and wind, more than 50% of Jordanian students are not aware of biofuels, such as biodiesel and bioethanol (Zyadin et al., 2012).

At the same time, students in Turkey do not seem to have sufficient information about biomass energy (Karatepe et al., 2012). Wind and solar energy are the sources most accepted by the public. In Greece, students rated solar, wind and hydroelectric energy sources as the most important for the country to invest in to become energy self-sufficient. However, they showed a reduced understanding of the promising potential of ocean thermal energy, wave energy, geothermal energy and bioenergy for Greece, as well as how these renewable sources, and in particular hydrogen fuel cell technology, could open important avenues for future research careers (Keramitsoglou, 2016). The impact of school on the knowledge area of RES is also presented in the research of Pambudi et al. (2024) where high school students in Indonesia, from different curricula, showed different cognitive performance regarding RES. Specifically,

students from technical vocational education and engineering high schools showed a significantly higher cognitive level than students from vocational high schools.

Students' attitudes towards RES are determined by a number of factors related to broader social and economic stimuli. Altuntaş & Turan (2018) confirm the correlation between Turkish secondary students' cognitive and affective awareness, as it appears that students' cognitive awareness about RES greatly influences their affective awareness. Students with insufficient knowledge about RES appear neutral in their use, while most students show interest in learning more about RES (Akinwale, 2022). Jordanian students consider RES as a sustainable energy option for the future and generally show a positive attitude and willingness to adopt RES, even at high prices (Zyadin et al., 2012). Junior high school students in Taiwan agree that RES should be developed regardless of their relatively higher cost, but they believe that technological progress should be accelerated to reduce costs and enhance the competitiveness of RES (Yeh et al., 2017). On the contrary, Çelikler & Aksan (2015) in their research on 7 and 8-grade students in Turkey report that more than half of students are hesitant to pay more for electricity produced from RES. This is also supported by Chen et al., (2015) who consider that Taiwanese students' positive views on RES are rather superficial and not accompanied by deep environmental values as they appear hesitant to assume the additional costs of their development and use. The same study presents the interesting finding that girls are more reluctant to pay additional costs for replacing fossil fuels with RES. This contrasts with the general trend seen in studies conducted in China (Li et al., 2022), Japan (Akitsu et al., 2017), Malaysia (Fah et al., 2012) and Turkey (Aktamis. 2011) where boys are less environmentally sensitive than girls, who appear to have more sustainable attitudes and behaviours towards the environment and energy or studies in Iran (Bahrami & Mohammadi, 2021) and Jordan (Zyadin et al., 2012), which no difference is recorded in the attitudes of the two genders.

Research in Turkish middle school students shows that girls have higher levels of knowledge than boys (Aktamis, 2011). Gender was found to significantly influence knowledge about RES but did not significantly affect awareness about non-renewable sources. However, girls appear to be better informed about non-renewable sources and more familiar with RES compared to boys (Zyadin et al., 2012). Furthermore, the level of awareness among girls is higher than that of boys in Palestine (Assali et al., 2019). In contrast, in a recent study, Akinwale (2022) concludes that gender is not statistically significant, indicating that students of different genders have the same level of awareness about RES (Akinwale, 2022). The same result is consistent with research conducted in high schools of various types in Indonesia (Pambudi et al., 2024). In research conducted in higher education, no differences in cognitive level were observed based on gender, but girls had greater awareness of RES than boys (El-Khozondar et al., 2020; Karatepe et al., 2012).

The worldview and the conceptual theoretical basis of students is mainly influenced by their environment and their experiences in it. According to Çoker et al. (2010), there is a shift in the sources of conceptual input of Turkish students depending on their age, which can be categorized into influences coming from their daily environment and influences they receive from the school environment. As can be seen from the differences between grades 4-5 and 9-12 in relation to energy concepts, the conceptual framework of the former mainly comes from the context of daily life. On the contrary, the conceptual framework of grades 9-12 mainly comes from the school environment. Therefore, as the age of the respondents' increases, their awareness levels also increase (Karatepe et al., 2012). Illias et al. (2020) believe that students at the upper secondary level in Malaysia have a better understanding of RES and are more aware of their environmental benefits. However, this does not lead to an increase in students' active behaviour and intention, as shown by the research of Yeh et al. (2017) on 8th grade students,

who had significantly more active behaviour and intention than 9th grade students. This showed a reduced intention to take action to save energy among high school students.

On the contrary, students' awareness increases with age (Altuntaş & Turan, 2018; Aktamis, 2011). These conclusions are confirmed by more recent research in Hungary, according to which students' knowledge about RES increases with age, although it is limited at each school level (Revak et al., 2019). However, according to Akinwale (2022), age is not statistically significant, indicating that students of different ages have the same level of awareness about RES. Based on these findings, we conclude that the secondary education learning process provides insufficient training to shape students' behaviour and active attitude towards RES (Aktamis, 2011).

Some students are unsure about RES and have misconceptions about this concept. Although students mention some RES, such as solar and wind, they incorrectly mention electricity as an energy source, which is not true, as "electricity" is not an energy source. A large percentage of student's state that batteries are RES, while in fact they are phenomena resulting from the presence and flow of electric charge, and cannot be described as energy sources (Çoker et al., 2010). Some of the student misconceptions that have been documented in many studies include: 1. Fossil fuels take hundreds of years to form and natural gas is renewable, 2. Solar panels operate on the heat of the sun, 3. Electricity produced in hydroelectric plants is stored, 4. Biogas does not harm the environment, 5. Gasoline is a biofuel, 6. Radioactivity is an inexhaustible and renewable source of energy, 7. RES do not harm the environment, 8. Heat and temperature are similar concepts. These misconceptions have been identified and persistent in several studies (Hull et al., 2021; Cheong et al., 2014; Tortop, 2012; Yeh et al., 2017; Çelikler & Aksan, 2015; Zyadin et al., 2012).

Individuals' environmental values and attitudes play an important role in sustainability issues. They influence, among other things, economic factors, the acceptance of society on issues such as the use of RES (Fobissie, 2019). Social psychologists use a range of research tools to detect the prevailing environmental consciousness of a society, with the NEP (New Ecological Paradigm) scale being a popular choice for most researchers as it is considered to have high predictive power (Dyr & Prusik, 2020; Arnold et al., 2018). The 15 items are divided into three into five factors of the ecological worldview: a) Eco crisis, b) limits to growth, c) anti-anthropocentrism, d) balance of nature and e) exception to the laws of nature (Dunlap et al., 2000). The NEP scale has shown predictive validity in many studies, but there are studies that criticize the scale as there is a discrepancy between them regarding the number of its dimensions, distinguishing more than one (Vdović et al., 2024). The NEP scale is applied in the following fields: a) environmental research, assessing attitudes and behaviours in relation to sustainability, b) education, evaluating the impact of environmental lessons and actions on students, c) policymaking, measuring the degree of support for environmentally friendly laws by citizens and d) market research, detecting citizens' ecocentric perceptions and using them to promote products on the market (Xiao et al., 2019). In Greece, Ntanos et al. (2019), among other things, investigated consumers' attitudes towards clean energy, with ecocentric perceptions being positively correlated with RES. Ecological sensitivity was positively correlated with both the willingness of respondents to cover any additional costs that would arise from the development of RES and with the perception that RES contribute to improving the environment. According to the researchers, society's attitude towards "green" investments becomes positive as its ecological sensitivity increases. However, in their study of secondary school students in Taiwan, Lee et al. (2015), recognized that the use of RES is an effective way to reduce greenhouse gases compared to the use of fossil fuels and nuclear energy, while they consider that RES are a practice that leads to the protection of the planet. The multitude of

studies and research as well as the variety of objects for which the NEP has been applied makes it clear that it is a powerful tool for detecting and predicting attitudes and behaviours in aspects of human activity related to the natural environment and sustainability (Gansser & Reich, 2023; Cordano et al., 2003).

3. Methodology

The target population for this study comprised students from the Attica region of Greece. The research was conducted during the 2021-2022 and 2022-2023 school years. The schools involved in the study were selected by means of a randomization. In the Attica region, there are seven secondary education directorates where the questionnaires were hand-delivered. The questionnaire was constructed after a thorough study of the relevant literature. The questions selected were translated from English to Greek by practicing teachers of English literature. All questions are closed-ended, a) multiple choice, b) two-valued and c) 5-scale Likert. Likert questions were used to detect students' pro-environmental attitudes and levels of perceived knowledge about renewable energy. Multiple choice questions were used to assess students' levels of objective knowledge about renewable energy.

A piloting pre-testing was conducted with 100 students that represented all grade levels of the high school. Some items of the questionnaire were altered so that the students were better able to understand them, but the meaning remained the same. A total of 50 lower secondary schools (gymnasium) were involved and 6161 were completed, during school hours. The sample of students included 51.9% girls and 48.1% boys. Regarding class distribution, 35.7% of the students were in the 7th grade (11-12 y.o.), 32.4% in the 8th grade (12-13 y.o.), and 31.9% in the 9th grade (13-14 y.o.), providing a balanced representation across lower secondary education levels. The students were given a questionnaire in person during the science lesson. The science teacher and the special education teacher were present in the classroom. A teaching period lasts 50 minutes and during this time the students handed in the completed questionnaire.

Given the main objectives of the study, the following five research questions were formulated, and qualitative analysis was conducted to answer them:

RQ1: What are students' levels of perceived and objective knowledge towards renewable energy?

RQ2: Do students with pro-environmental attitudes have better factual knowledge about renewable energy?

RQ3: How do students' characteristics, knowledge, and pro-environmental attitudes predict their support toward renewable energy initiatives?

Objective knowledge is the knowledge an individual demonstrates when a certain situation requires or on a knowledge test (Radecki & Jaccard, 1995). On the contrary, perceived knowledge has not an objective character, it is a subjective self-assessment of an individual about his understanding on a topic. Perceived knowledge is influenced by individual's intrapersonal factors, and it frequently shapes his perceptions and intentions (Granderath et al., 2021; Radecki & Jaccard, 1995; Schäfer, 2020). Pro-environmental attitude is a positive disposition towards environmental wellbeing leading to support of actions that promote sustainability and hinder choices that have negative impact on balance of nature (Bellotti et al., 2025; Shen et al., 2024).

Perceived knowledge of renewable energy was measured using a single self-assessment question: "How would you rate your knowledge of renewable energy?" Thus, in terms of perceived knowledge, students rated their familiarity with renewable energy on a 1–5 scale. Objective knowledge was assessed through eight factual multiple-choice questions on topics such as the share of renewables in Greece, examples of RES, and the use of biofuels. Each correct answer was coded as 1 point, incorrect or missing answers as 0. Scores were summed to create a total objective knowledge score ranging from 0 to 8, with higher scores indicating greater factual knowledge about renewable energy. Students' overall pro-environmental attitudes were measured using a mean score calculated from responses to 15 Likert-type items assessing beliefs about human-nature relationships (e.g., "Humans interfere too much with nature," "Plants and animals have equal rights") and anthropocentric views (e.g., "It is right for humans to change nature as they wish"). Each item was rated on a 5-point scale (1 = strongly disagree, 5 = strongly agree). The attitude score was computed by averaging the numerical responses to all answered items, resulting in a continuous variable ranging from 1 (consistently negative attitudes toward environmental stewardship) to 5 (consistently strong pro-environmental attitudes). Missing responses were handled by calculating the mean over non-missing items, ensuring students with partial data were retained if they answered a majority of items.

Descriptive statistics were used to identify students perceived and objective knowledge as well as the environmental attitudes. A linear regression analysis is performed with a dependent variable the objective knowledge score and independent the attitude score towards renewables. In order to estimate how students' characteristics, knowledge, and pro-environmental attitudes predict their support toward renewable energy initiatives an econometric analysis was performed.

4. Results

The following section presents the empirical results of our study, organized by research question, employing a combination of statistical and econometric techniques.

Students' levels of perceived and objective knowledge about renewable energy (RQ1)

In terms of perceived knowledge, students rated their familiarity with renewable energy on a 1–5 scale. Specifically, 5.8% of students rated themselves as having very poor knowledge, 13.9% as poor, 48.6% as moderate, 29.1% as good, and only 2.6% as expert. Regarding objective knowledge, the distribution of correct answers across the eight factual questions was as follows: 2.08% answered zero correctly, 8.44% answered one correctly, 16.75% answered two, 22.07% answered three, 20.50% answered four, 15.87% answered five, 9.46% answered six, 4.09% answered seven, and 0.73% answered all eight correctly. This pattern indicates that while most students perceive themselves as having moderate or good knowledge, in practice, a majority scored three to five correct answers, with fewer than 15% demonstrating high factual knowledge (six or more correct).

Table 1 presents students' performance on eight factual questions assessing objective knowledge about renewable energy and related concepts. The results reveal substantial variability across items, indicating uneven knowledge among students on different aspects of renewable energy. The highest percentage of correct responses was observed for the question on reducing energy consumption at home, with 88.9% of students answering correctly,

suggesting good practical awareness of everyday energy-saving behaviors. Similarly, identifying an example of a renewable energy source showed a high correct response rate of 78.5%, reflecting widespread familiarity with at least basic examples of renewables, such as solar or wind power.

Conversely, the lowest performance was recorded on the question about the main source of biofuels, where only 27.4% of students provided the correct answer. This indicates a major knowledge gap regarding bioenergy, an important but often less visible aspect of renewable energy systems. Additionally, only 33.1% of students correctly identified the most widely used renewable energy source in Greece, revealing limited knowledge of their country's energy mix. Regarding conceptual understanding, only 52.6% correctly defined energy efficiency, showing that many students struggle to grasp this foundational concept for sustainable energy use. Questions addressing more general environmental knowledge, such as the gas contributing most to the greenhouse effect (correct for 59.8% of students) and identifying non-RES (68.7% correct), demonstrated moderate success but leave considerable room for improvement.

Overall, these results highlight that while students show reasonable knowledge of obvious or widely discussed topics—like household energy-saving and basic renewable sources—there are significant deficiencies in their understanding of critical but less publicly emphasized areas, such as biofuels, national energy priorities, and key energy efficiency concepts. Addressing these gaps through targeted energy education could better equip students to make informed decisions and participate meaningfully in discussions about Greece's energy future.

Table 1. Students' objective knowledge toward renewables and related topics

Objective Knowledge Question	% Correct answer	SD	Min	Max
What share of Greece's electricity comes from renewables?	41.2%	0.49	0	1
Identify an example of a renewable energy source.	78.5%	0.41	0	1
Which of these energy sources is not renewable?	68.7%	0.46	0	1
What is the main source of biofuels?	27.4%	0.44	0	1
Name the most widely used renewable energy source in Greece.	33.1%	0.47	0	1
Which of the following best describes energy efficiency?	52.6%	0.50	0	1
Which gas contributes most to the greenhouse effect?	59.8%	0.49	0	1
Identify one way to reduce energy consumption at home.	88.9%	0.31	0	1

Source: Authors' calculations.

Relationship between pro-environmental attitudes and factual knowledge about renewable energy (RQ2)

Pro-environmental attitudes were assessed, and the results are presented in ***Table 2***, via summary statistics of students' responses about the attitude items used in the analysis. Higher scores indicate stronger overall pro-environmental attitudes.

As regards the key pro-environmental attitude items analysed, the percentage distributions were as follows: on the statement "Humans interfere too much with nature", 44.39% strongly agreed, 39.51% agreed, 10.1% were neutral, 4.7% disagreed, and 1.3% strongly disagreed. For "Plants and animals have equal rights", 56.63% strongly agreed, 23.71% agreed, 13.1% neutral, 5.1% disagreed, and 1.5% strongly disagreed. For the statement "It is right for humans to change nature as they wish", only 4.08% strongly agreed and 9.92% agreed, while 36.5% were neutral, 35.4% disagreed, and 14.1% strongly disagreed, showing a clear rejection of anthropocentric beliefs. Regarding the idea that "Nature can cope with any human use" results showed similarly low agreement (5.3% strongly agree, 9.8% agree) and high disagreement (47.2% disagree or strongly disagree). These patterns highlight overall strong pro-environmental attitudes with majority agreement to eco-centric items and widespread rejection of anthropocentric views.

Table 2. Summary statistics of students' pro-environmental topics

Attitude Item Statement	Mean	SD	Min	Max
Humans should limit their exploitation of nature	4.02	0.86	1	5
It is right for humans to change nature as they wish	2.19	1.12	1	5
Humans interfere too much with nature	4.21	0.78	1	5
Human inventions can solve any environmental problem	2.88	1.02	1	5
The way humans use resources is destructive	4.17	0.81	1	5
Renewable energy development helps protect the environment	4.12	0.83	1	5
Plants and animals have equal rights with humans	4.35	0.74	1	5
Nature is powerful and can recover from human impacts	2.67	1.09	1	5
Natural laws should guide human behavior	3.88	0.90	1	5
Humans should respect the balance of ecosystems	4.24	0.77	1	5
Earth's resources are like those of a spaceship and must be conserved	3.99	0.87	1	5
Governments should do more to protect the environment	4.28	0.79	1	5
Environmental sensitivity should guide energy decisions	4.05	0.84	1	5
Humans can control nature completely	2.11	1.07	1	5
Environmental destruction should be stopped immediately	4.31	0.76	1	5

Source: Authors' calculations.

Next, in order to test whether pro-environmental attitudes affect factual knowledge about renewable energy a linear regression analysis is performed with a dependent variable the objective knowledge score and independent the attitude score towards renewables. Results are presented in ***Table 3***.

Table 3. Estimated simple linear regression of pro-environmental attitudes predicting students' objective knowledge toward renewables

Predictors	Coef. (β)	95% CI	p-value
Intercept	2.239	[2.087, 2.391]	0.001
Attitude score	0.262	[0.178, 0.347]	0.001
Model fit:			
$F(1,6159) = 33.7$, $p<0.001$			
$R_{adj}^2 = 0.20$			

Source: Authors' calculations.

The regression analysis revealed a statistically significant positive relationship between students' pro-environmental attitudes and their factual knowledge about renewable energy. Specifically, for every one-unit increase in attitude score, objective knowledge increased by 0.262 correct answers. 20% of the variability in students' objective knowledge towards renewables is explained by their pro-environmental attitudes. Considering also that $p<0.001$, the model appears to have a moderate but statistically significant explanatory power. Thus, findings suggest that positive environmental attitudes are not strongly associated with higher objective knowledge.

Determinant factors of students' perceptions towards renewable energy initiatives (RQ3)

A large majority of students demonstrated willingness to expand renewable energy production ("Greece should produce more renewable energy"), 30.38% of students strongly agreed, 31.63% agreed, 24.1% were neutral, 10.1% disagreed, and 3.8% strongly disagreed, resulting in 62% overall positive responses. However, enthusiasm declined when costs were considered ("I support renewable energy initiatives even if it increases energy costs"). Specifically, willingness to support renewables even if it increased costs dropped to 15.14% strongly agreeing and 29.51% agreeing, with 29.4% neutral, 17.6% disagreeing, and 8.5% strongly disagreeing, leading to 44.6% positive responses. Support dropped further for building wind farms in scenic, agricultural, or wildlife areas, with only 9.5% strongly agreeing, 18.52%

agreeing, 30.5% neutral, 27.4% disagreeing, and 14.1% strongly disagreeing, amounting to just 28% positive responses ("I support building wind farms even in scenic, agricultural, or wildlife-sensitive areas"). These distributions show how support decreases significantly under economic or environmental trade-offs, especially regarding the siting of wind farms. Next, the MANOVA results demonstrated that both gender and educational level significantly shaped students' willingness profiles. Specifically, there were significant main effects for gender (Wilks' λ=0.997, $F(3,6156)=5.60$, $p<0.001$) and educational level (Wilks' λ=0.995, $F(6,12312)=4.60$, $p<0.001$), indicating that students' openness to renewable energy initiatives varies systematically across these demographic dimensions. These findings suggest the need for targeted educational strategies and communication campaigns that account for differences in both gender and educational stage to more effectively engage students and foster deeper, actionable support for renewable energy policies.

Next econometric analysis is performed to estimate how students' characteristics, knowledge, and pro-environmental attitudes predict their support toward renewable energy initiatives. Results are presented in ***Table 4***.

Table 4. Estimated multiple regression models predicting students' support toward renewable energy initiatives

Dependent variables	**Model I** **Greece should produce more renewable energy**		**Model II** **I support renewable energy initiatives even if it increases energy costs**		**Model III** **I support building wind farms even in scenic, agricultural, or wildlife-sensitive areas**	
Predictors	**Coef. (β)**	**p-value**	**Coef. (β)**	**p-value**	**Coef. (β)**	**p-value**
Intercept	1.118	<0.001	2.211	<0.001	2.612	<0.001
Gender	0.154	<0.001	0.013	0.604 (n.s)	0.237	<0.001
Class	0.066	<0.001	0.027	0.092 (n.s)	0.009	0.606 (n.s)
Self-assessed knowledge	0.107	<0.001	0.101	<0.001	-0.039	0.034 (n.s)
Objective knowledge score	0.0375	<0.001	0.011	0.001 (n.s)	-0.018	<0.001
Attitude score	0.446	<0.001	0.411	<0.001	0.359	<0.001
Model fit:	F (1,1152) =23.6, p<0.001		F (1,211) =31.8, p<0.001		F (1,5189) =29.7, p<0.001	
	$Radj^2$=0.2466		$Radj^2$=0.1265		$Radj^2$=0.219	

Source: Authors' calculations. n.s denotes no statistical significance.

Results for Model I suggest that a positive synergy exists between schooling progression, knowledge, and attitudes in shaping general support for renewables. 23.6% of the variability in student's support on producing more renewable energy in Greece is explained by the Model I. More precisely, older students (higher grades) are more willing to support increasing renewable energy production (β=0.066, $p<0.001$). This suggests that as student progress through Gymnasium, they may gain more exposure to environmental topics or develop greater maturity, leading to stronger support for renewables in principle. It is also estimated that females (gender is coded as higher value) show higher willingness than males (β=0.154, $p<0.001$), consistent with research indicating women often express stronger pro-environmental attitudes. As far as self-assessed knowledge (β=0.107) and objective knowledge (β=0.0375), both significantly predict greater willingness towards more production on renewables. This means students who think they know more — and those who actually know more facts — are more supportive of renewables. Finally, results support that the strongest predictor is pro-environmental attitude, and students with stronger pro-environmental attitudes are much more willing to support renewables.

In this scenario involving personal financial trade-offs, students' willingness dropped significantly. In particular, in case of Model II, schooling level and gender did not significantly influence support towards renewables in case of increased costs. However, self-assessed knowledge (β=0.101) still predicted slightly greater willingness to accept higher energy costs. Again, pro-environmental attitudes (β=0.411, p<0.001) emerged as the strongest predictor, indicating that students with stronger environmental values are more willing to bear increased costs for renewable energy — but overall, the effects of knowledge and attitudes were weaker than for general support.

Pro-environmental attitudes remained the strongest positive predictor (β=0.359, p<0.001), helping to offset some resistance to wind farms in controversial locations (Model III). 21.9% of the variability in student's support on building wind farms even in environmentally sensitive areas is explained by the Model III. Females showed significantly more willingness than males (β=0.237, p<0.001), but level of class had no significant effect. In this case, knowledge had an inverse relationship (β=-0.018, p<0.001), since students with higher objective knowledge were less willing to support wind farms in sensitive areas, likely reflecting increased awareness of potential local environmental or landscape impacts. Thus, while positive attitudes encourage support, more knowledgeable students may be more aware of negative local impacts of wind farms, leading them to oppose siting renewables in sensitive areas.

5. Discussion

In this study, Greek lower-secondary students' willingness to support renewable energy across three scenarios, each corresponding to a different dimension of real-life renewable deployment, that is, general expansion ("Greece should produce more renewable energy"), financial trade-offs ("I support renewable energy, even if the energy costs will be higher"), and local environmental trade-offs ("I support the construction of wind farms even in scenic, agricultural, or wildlife-sensitive locations") was investigated.

The strongest and most consistent predictor of willingness across the presented scenarios was the students' pro-environmental attitudes. Students with more positive attitudes towards the pro-environment were significantly more likely to accept renewable energy either in principle, even if costs are higher or if sited in sensitive locations. This result is consistent with well-grounded literature that positive environmental attitudes are among the most powerful predictors of pro-environmental intentions and behaviors (Liu et al., 2020). Indeed, the strong attitude scores in all three models is indicative of the importance of instilling environmental values early in education as a basis on which to build support for renewable energy.

Knowledge showed complex, scenario-dependent effects. In the general expansion and cost acceptance models, both subjective and objective knowledge were associated with increased support for renewable energy. These results correspond to previous results showing that increased awareness will lead to engagement in sustainable behaviors (Cogut et al., 2019; Amel et al., 2009). Yet in the third case of acceptance—of wind farms in sensitive areas—both forms of knowledge were significant predictors of willingness to be less supportive. This negative association between the two indicates informed pupils may also be familiar with potential local downsides to these same sources, such as visual intrusion, noise, or conservation considerations, which are frequently at the heart of community resistance in the case of wind. This is consistent with the notion that while information may be needed to make enlightened choices, it might also create more discerning or even sceptical attitudes, particularly when local

environmental or social trade-offs are involved with the planning of renewable projects (Mancini & Raggi, 2022; Kosenius & Ollikainen, 2013).

Demographics had mixed effects. Females were also more willing to consent than males in the in the increase in renewable energy production (Model I) even if wind turbines were installed in rural or scenic areas (Model III). This result is consistent with early studies that found evidence of stronger environmental concern and support for sustainability efforts among women (Sakellari, & Skanavis, 2013; Braun, 2010). In both models, class level, indicating that when students grow older in junior high-school, they are more willing to accept to expand on renewable energy production. But school class did not matter when these scenarios also mentioned cost or local environmental factors (Pascaris et al., 2021; Chen et al., 2015). This suggests that general support for renewables (which could be expected to increase with age or educational exposure) is not the same as willingness (in the presence of such difficult trade-offs) under cost scenario.

All in all, these findings highlight the complexity of the knowledge and attitude relationship to renewable energy acceptance. Positive attitudes are a consistent influence on support, while knowledge can actively reinforce willingness (when the trade-offs are financial), or reduce it (when the trade-offs are local). These results suggest the need for educational approaches that not only aim at mastering subject related knowledge and fostering positive attitudes, but that also stimulate critical thinking, as well as problem solving strategies, in dealing with the multi-dimensionality of renewable energy issues. Programs must specifically include issues of typical trade-offs, fair considerations, and opportunities for balancing national energy goals with local community and environmental needs.

6. Conclusion

This research provides comprehensive evidence of Greek lower-secondary students' awareness, attitude towards support to renewable energy. Findings show that whereas students think of themselves as being moderately knowledgeable, their actual knowledge—especially about less visible issues including bioenergy and Greece's energy mix—is limited. Pro-environmental attitude turned out to be the single most robust and consistent predictor of support for renewables initiatives, at both a general level and in the face of trade-offs. But knowledge exhibited complicated effects – it increased overall support but also increased caution for local environmental factors. These results emphasize the relevance of encouraging accurate knowledge and positive attitudes in environmental education to create well-informed and active future energy citizens able to critical thinking and acting toward the complexities of the energy transition.

The results in this study carry significant implications of policy in education, and outreach campaigns for renewable energy. In particular, there is a strong need to update the environmental education curricula to remove the existing holes in students' knowledge about less common, but equally important subjects, including bioenergy and the particular energy mix of Greece, so that students keep an adequate image of renewable energy systems within their minds. Second, as pro-environmental attitudes are the most important predictors of renewable support, there is good cause for policymakers and educators to also work on programs and initiatives that stimulate such attitudes at an early age as positive attitudes toward nature can be expected to outweigh future commitment. Third, because knowledge exhibited nuanced effects - including, at times, lowering willingness in the presence of local environmental trade-offs -

education programs would benefit from looking beyond the mere provision of facts to include training for students on critical thinking, so that they can thoughtfully weigh-in on the multi-dimensional nature of renewable energy deployment in society. In addition, personalized communication approaches based on the gender differences observed in this study might also help to improve engagement by taking the specific viewpoints of boys and girls into consideration. In the end, a combined approach creating both sound knowledge and positive personality would better prepare young citizens to actively participate in Greece's and Europe's active energy transition.

Although the study offers valuable contributions, several limitations need to be recognized that can serve as suggestions for future research. The sample was limited to Greek students; therefore, it is large and diverse but not necessarily representative of students in other cultures/students all over Europe. To be able to test such comparisons and generalize these findings to other socio-cultural settings, comparisons with data from other European countries should be added to the research design. Furthermore, self-reports of perceived knowledge and attitudes can be biased by social desirability, possibly overestimating the importance of pro-environmental attitudes in students. Finally, the analysis did not consider the influence of parental, household or community contexts, social media exposure that may have a large impact on young people's environmental knowledge and attitudes, therefore perhaps missing out on an important influence. In addition, intervention studies testing the efficacy of particular energy educational approaches (e.g., experiential learning, environmental projects, interactive digital tools) could help discover best practices to the dual effect of enhancing the objectivist knowledge and promoting positive environmental attitudes. Research into the contribution of teacher preparation and school resources to the development of programs of renewable energy education could provide important insights for policy and practice.

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