Macrothink Institute™

Journal of Environment and Ecology
ISSN 2157-6092
2025, Vol. 16, No. 1

Energy Literacy and Sustainability Aspects: Evidence from Greece

Eleni Sardianou

Professor, Department of Economics and Sustainable Development

Harokopio University of Athens

70 El. Venizelou Str., 17671 Kallithea, Greece

E-mail: esardianou@hua.gr

Konstantinos Kougias (Corresponding author)

Phd Candidate, Department of Economics and Sustainable Development

Harokopio University of Athens

70 El. Venizelou Str., 17671 Kallithea, Greece

E-mail: : kkoygias@hua.gr

Received: May 24, 2025 Accepted: June 12, 2025 Published: June 25, 2025

doi:10.5296/jee.v16i1.22885 URL: https://doi.org/10.5296/jee.v16i1.22885

Abstract

Energy education is an integral part of energy, environmental and economic literacy. Energy literacy is a multidimensional concept and its possession leads to an energy autonomous and secure society. However, little attention has been paid to the energy literacy of Greek secondary school students. This research aims to shed light on aspects related to the energy education of Greek students. The importance of this research stems from the need for students to be energy literate in order to have the ability to make appropriate decisions as future consumers. Primary data were collected in the Attica region by distributing a questionnaire. The results show that students have incomplete and fragmentary knowledge about energy. School appears as their main source of information while they state that they discuss a lot about saving energy in their family, for which they have a positive attitude. Students appear to have behaviours that promote sustainability. Girls seem to present more responsible attitudes towards environmental issues. Higher grade students tend to be more accurate on knowledge questions. The results do not reveal statistically significant differences

between students who participate and those who do not participate in environmental organizations. Three energy literacy profiles were identified by the analysis: a) informed but passive, b) active and sensitized and c) moderately informed and inactive. As educational programs in Greece are undergoing a transformation process, this research could be a powerful tool for education policy makers. It is recommended that these programs be oriented towards energy sustainability.

Keywords: Middle school, energy literacy, latent group analysis

1. Introduction

The appearance of man on the planet added another link to the existing conversions of solar energy into other forms. If we consider that the burning of wood existed before the appearance of man, the use of fossil fuels as a dominant source of energy, which fueled human development and civilization, continues today, in the era of the 4th industrial revolution, to be one of the foundations of modern society (Hermann et al., 2016; Vlachogianni & Valavanidis, 2013). For this reason, energy as a concept has been the subject of discussion and reflection for the last century (Das & Richman, 2022). Energy is a good for which there is a large gap between the extent to which it is used and the knowledge we have about it, while the way it is used can have consequences for the current generation and for the next (Armaroli & Balzani, 2007). The intensifying energy crisis and global warming are examples of inefficient energy management that are timeless (Wang et al., 2023; Schweiger, 2020).

People base their economic development, technological progress, improved quality of life and well-being on energy sufficiency and security (Rao & Wilson, 2022; Lay et al., 2013). Today, people's energy needs continue to increase, as they live in a world of high energy demands that are fueled and changed by population growth, economic development, climate change, industrialization, urbanization and unpredictable events that affect societies, such as the COVID-19 pandemic (Szczygielski et al., 2024; Van Ruijven et al., 2019; York, 2016). This has an impact on energy costs, which directly or indirectly affect the value of all goods and services produced and, by extension, inflation and economic growth (Borisov, 2024; Barrett, 2022). Simultaneously, the reduction of easily available fossil fuel reserves and environmental change leading to restrictions on their use, are driving human societies towards choices and decisions that will reduce energy risk and promote energy sufficiency (Ulussever et al., 2025; Brounen et al., 2013; DeWaters & Powers, 2011). Choices will not be made only by politicians and energy policy makers, but by all members of society, as energy use and its impacts are a collective responsibility. This means that it is necessary for citizens to be sufficiently informed about energy, its consumption, and ways to save it, in order to adopt sustainable practices and habits (Steg et al., 2015; Lay et al., 2013). Knowledge about energy and its internalization should begin from the age when a person forms attitudes, opinions and behaviors, that is, from their school years, mainly through the formal or informal educational process, but also the influence of their family and social environment (Rets et al., 2024; Ayata et al., 2024; Seyedabadi et al., 2024; Hasanah et al., 2023; Khuc et al., 2023; Stylos et al., 2023; Chandrasenan, 2022; Varghese & Chandrasenan, 2022;

Poimenidis & Papavasileiou, 2021; Pearce et al., 2020; Akitsu & Ishihara, 2018). The impact of citizens on the energy balance is very important, as domestic use constitutes a very large part of the total energy consumption of a society (Faia, 2025). This fact highlights the need to implement practices in education that connect science teaching with people's daily needs and the experiences they gain throughout their lives. In this way, the sterile acquisition of knowledge is gradually transformed into scientific knowledge, leading to the adoption of attitudes and perceptions and, ultimately, to sustainable energy behaviors (Pradana et al., 2019; Karpudewan et al., 2016; Chen et al., 2015a; Bennett et al., 2007). This transformation of attitudes and behaviors leads to: a) decision-making, b) improved security, c) economic growth, d) reduced environmental risk and e) economic sustainability (US DoE, 2017).

In Greece, energy education is not an autonomous discipline. Energy-related topics are scattered and integrated into different teaching subjects. Therefore, students are provided with knowledge in a fragmented manner. Students' energy literacy is very important as it can bring significant benefits at an individual and social level and determine the energy orientation of the country. The innovation of the study relies on the three student groups of different attitudes and cognitive and behavioural characteristics revealed by latent group analysis. The distinction of these groups is of practical importance as for each group a different educational approach towards energy literacy can be followed. The study contributes to the understanding of students' energy literacy in Greece, proposing an empirically grounded and statistically robust approach for shaping educational policy and enhancing sustainability in the school environment so it could be a powerful tool for educational secondary program planners.

2. Literature Review

Environmental education is not part of the Greek middle school curriculum. It is mostly an add on activity, limited to projects that take place after school hours, the implementation of which is based on the willingness of teachers and students. Energy education in Greece is fragmented. Energy issues are addressed integrated into chapters of different disciplines, mainly natural sciences.

2.1 About energy literacy

In recent decades, energy literacy has become a subject of study and interest for the scientific community. There is no universally accepted definition of the term “energy literacy”. That varies depending on the researcher and the researcher's interest, resulting in no commonly accepted definition but a series of mutually complementary formulations that can be unified into a broader and more generalized one (Martins et al., 2020a). According to DeWaters et al. (2007) the term energy literacy does not only refer to knowledge about energy in the narrow sense but also includes a deep understanding and internalization of these as well as behaviours and attitudes towards issues related to the use of energy in everyday life. DeWaters & Powers (2008, 2011) mention as an essential component of the individual’s energy literacy, an understanding of how energy is used in everyday life and the impact this has on the environment and society, in addition to a coherent conceptual base of knowledge about energy. They consider as basic knowledge the ways of saving energy and its environmentally friendly use as well as an understanding of the development of alternative

ways of energy production. They believe that an energy literate person understands the implications of energy-related decisions on a local and global scale, demonstrates behaviours that reflect energy-sustainable attitudes, and takes appropriate actions. Based on the above, they define energy literacy in three distinct areas, a) cognitive (basic energy concepts, energy sources and resources, environmental/social impacts), b) affective (sensitivity/awareness of global energy issues, positive attitudes towards energy, beliefs) and c) behavioral (intention for sustainability, decisions based on thinking, support for change). Subsequent researchers have sought to link energy literacy to issues that have a clear economic basis. Brounen et al. (2013) relate it to the decision that an individual will make about the cost of an investment related to the procurement of equipment to improve energy efficiency and whether this cost will be compensated in the long term by the energy savings that this expenditure entails. This presupposes, in a broader definition of energy literacy formulated by Gołębiowska (2020), knowledge of the energy market, the energy consumption of devices, but also awareness of the environmental impacts of energy consumption. Kalmi et al. (2021) acknowledge that it is a broad and holistic concept that is more related to engineering and natural sciences than to economics. However, they give a clear economic basis to the definition they formulate as they consider that energy literacy refers to the awareness of individual energy consumption, the process followed to define the final price of energy, the intention to adopt energy-saving behaviours and the individual's pursuit of access to energy-related information. Blasch et al. (2018) link economics more closely to energy literacy by introducing the term "energy-related financial literacy". The term links energy knowledge, i.e. the information an individual need to make informed decisions about energy, and information processing skills, i.e. the cognitive skills necessary to analyse and utilize information and lead to economically viable choices. In summary, they define the combination of energy knowledge and cognitive skills necessary for making decisions about investing in the production of energy services and their consumption as energy-related financial literacy. They believe that the definition incorporates two critical elements for making informed and sound investment decisions in the energy sector: knowledge and the ability to process information. The United States Department of Energy advocates in this direction that energy literacy includes an understanding of the concept of energy, the function it performs in the natural and human-made environment, and the ability of the individual to use this knowledge to solve problems.

The U.S. Department of Energy (2017) provides a broader view, stating that energy literacy includes understanding the nature and the role of energy in the world and in everyday life, combined with the ability to apply that understanding to answer questions and solve problems. An energy literate individual demonstrates the following characteristics:

1. Understanding energy systems: Can monitor energy flows and think in terms of energy systems.

2. Awareness of personal energy use: Knows how much energy they consume, for what purposes they use it, and where the energy comes from.

3. Evaluating energy information: Has the ability to evaluate the reliability and validity of

energy-related information.

4. Effective Energy Communication: Can participate in meaningful discussions and share knowledge about energy and its use.

5. Informed Decision Making: Able to make informed decisions about energy use, considering the impacts and consequences of their choices.

Energy literacy enables individuals to understand the complexities of energy use and its impacts, promoting a more sustainable and informed approach to energy consumption and conservation.

Van den Broek (2019) introduced a comprehensive typology of energy literacy, distinguishing it into four main types:

a) Appliance Energy Consumption Knowledge: Refers to an individual's understanding of how much energy various appliances consume. It includes awareness of the operational efficiency and energy costs associated with specific appliances.

b) Energy literacy in relation to energy-saving actions at home: Reflects an individual's ability to evaluate the effectiveness and impact of various energy-saving measures, such as using energy-efficient appliances, insulating openings or adjusting the temperature.

c) Economic energy literacy: Relates to the ability to make cost-effective decisions about energy use. It includes understanding utility bills, analysing the cost-benefit of energy-saving investments and recognizing the economic impacts of energy choices.

d) Multidimensional energy literacy: Includes the three previous categories while also incorporating more general attitudes, values and behaviours towards energy conservation. It reflects a holistic approach to energy literacy, integrating knowledge, skills and motivation for action that promotes energy efficiency and sustainability.

This typology highlights the multidimensional nature of the term and highlights the importance of combining knowledge, practical skills and values to promote sustainable energy behaviours.

An energy literate person emphasizes on sustainability according to Akitsu et al. formulation. They believe that an individual who has energy literacy, in addition to their knowledge of energy issues, understands the use of energy in everyday life and how excessive consumption affects society and the natural environment. In this context, an energy literate individual can perceive the benefits of energy conservation and the introduction of clean forms of energy into a society's energy mix, giving them the ability not only to make appropriate energy choices but also to take action towards a society with a sustainable orientation (Akitsu et al., 2017). Martins et al. (2020b) believe that in order to make informed decisions related to energy, in addition to knowledge about energy, the individual should have certain basic economic concepts and the necessary skills to perform financial calculations. Therefore, they follow the DeWaters & Powers approach by adding the economic component to the cognitive domain. That is, their approach includes knowledge in the fields of energy

and economics, the possibilities that this knowledge provides, sensitivity to energy issues and the need to change energy consumption habits, the perception of the individual role of each citizen and behaviour or decision-making.

In the same vein, Chen et al. (2015a) formulate four dimensions and a total of nine indicators that organize the framework of energy literacy, giving, like Akitsu et al., an emphasis on sustainability but with a greater focus on it. In summary, the dimensions (and indicators in parentheses) that are proposed are:

I. Concepts related to energy. Indicators: a) Knowledge about energy, its production, b) systematic knowledge and c) understanding of energy costs)

II. Aetiology of energy issues. Indicators: a) Analysis of energy issues at the local and international level and b) evaluation of information related to energy issues.

III. Lifestyle that leads to low carbon emissions. Indicators: a) Consumption with sustainable characteristics and b) recognition and adoption of "green" technology

IV. Responsibility of citizens for a sustainable society. Indicators: a) Information and self-efficacy and b) citizen engagement.

In recent years, critical energy literacy has become an emerging theory based on critical theory and leads to the identification and effort to address social inequalities in every field of human activity (Lowan-Trudeau & Fowler, 2022). Since its emergence at the beginning of the last century by the Frankfurt School, critical theory incorporates knowledge from various dimensions and constructs of human thought such as philosophy, psychology and culture. In its modern version, it examines social and cultural power structures, the reforms promoted by the recognition of the multidimensional relationships of political and social aspects of human activity and confronts with scepticism the economic end in itself of human actions (Horkheimer, 1972; Nieto & Saiz, 2011; Thomson, 2016; Sandberg et al., 2019). Lowan-Trudeau & Fowler consider that critical energy literacy implies a critical understanding of the social, environmental, political and economic challenges as well as the benefits and impacts of the development and use of various energy sources and technological developments. The definitions that have been given for energy literacy largely cover the indicators of sustainable development. Sustainability, whether we consider it as defined in the Brundtland report (Brundtland, 1987) as the interaction of three pillars: environment, economy, society, or additional later approaches with the interaction of additional pillars such as institutions and culture (Ramcilovic-Suominen & Pülzl, 2018; Leal Filho et al., 2015; UCLG, 2010) and the spiritual pillar (Leal Filho et al., 2015; Rockefeller, 2010), has many points of intersection with energy literacy and the sustainable use of energy that it implies. As much attention has been paid to the progress of the economic pillar, in contrast to the environment and society (Halkos & Gkampoura, 2021), energy literacy can be the conceptual concept that can lead to holistic sustainable development. We can therefore define energy literacy as the knowledge and skills that lead the individual to environmentally sustainable attitudes regarding the production and consumption of energy, to the manifestation of daily behaviours that benefit both economically and society, and to the making of decisions that

promote energy efficiency and obey social and environmental ethics.

2.2 The influence of gender, age and environmental actions on energy literacy

The multidimensional structure of the concept of energy literacy depends on a significant number of factors such as age, gender, school curriculum, environmental attitudes, socioeconomic factors, local scale events, personal experiences, parents' educational level, energy bill payments, advertising campaigns etc. (Kumari et al., 2025; Hidalgo-Crespo, 2022; Kumar, 2019; Blasch et al., 2018; Yeh et al., 2017; Sovacool & Blyth, 2015; Bodzin et al., 2013; Dijkstra & Goedhart, 2012; Brutscher, 2011; Räty & Carlsson-Kanyama 2010; Ballantyne et al., 1998). Students' age and gender are the determinants of energy literacy that present correlation with energy literacy, in contrast to participation in environmental organizations and actions, which has not been adequately studied.

2.2.1 Age

Students' age may affect the development of their energy literacy, as their cognitive abilities and experiences evolve over time. Chen et al., (2015a) studied middle school students in Taiwan. They noted that 7th grade students performed worse on the knowledge and behaviour dimensions than those of 8th and 9th grade, except for the subsection "civic responsibility for a sustainable society". This is considered by the researchers to be because the third grade students may have more advanced knowledge about energy, as they have been involved in energy saving practices at various stages of education. For "civic responsibility for a sustainable society", there was no statistical difference between middle school students despite the fact that the scores on the behavioural scale are slightly higher for 7th grade students. In a similar study of students in Japan, Akitsu et al. (2017) found that 8th and 9th grade students scored higher than 7th grade students on the cognitive subscale. On the emotional subscale, 8th grade students scored higher than 7th grade students, while there was no significant difference on the behavioral subscale. On the contrary, there are studies that do not note differences in the cognitive component for students in relation to age (Lee et al., 2015). The same conclusion is recorded in higher education where age does not seem to be a determining factor for knowledge on energy issues (Jaber et al., 2017). The development of energy literacy concerns all students, regardless of age, however, teaching strategies and teaching models must be adapted to the cognitive abilities and interests of students of each age group, in order to achieve optimal understanding of energy concepts (Yeh et al.,2017; DeWaters & Powers, 2013).

2.2.2 Gender

Gender in a series of studies is a determining factor for students' energy literacy in many of its dimensions. This is supported by a series of studies in which it is found that men are more receptive to scientific knowledge (Barrow and Morrisey, 1987; Gambro and Switzky, 1999; Jaber et al. 2017) leading to the conclusion that men have a higher cognitive level on energy issues than women. When examining gender differences, Kuhn (1979) found that girls are more concerned about the need to save energy than boys, while Lawrenz & Dantchik (1985) using Kuhn's questionnaire found that girls, following the difference in emotional

development of the two sexes, tend to have a more positive attitude towards energy issues than boys. Barrow & Morrisey's (1987) study of high school students found a significant difference between boys' and girls' energy attitudes in Maine and a near-significant difference in New Brunswick. This, the researchers said, was expected given the close relationship between energy-related topics and science. Previous studies have not shown any gender differences (Holden & Barrow, 1984). Lee et al. (2015) found a gender effect in their study of Taiwan in the emotional domain. Women tended to have more positive attitudes and values. The increase in the influence of gender with age aligns with previous work (Martins et al., 2020; DeWaters and Powers, 2011; Lawrenz and Dantchik, 1985) and appears to be related to the hypothesis that women may be more amenable to progressive change as they move to higher levels in the educational system. Although male students had significantly higher knowledge about energy than female students, there was no correlation in their attitude scores, which is consistent with the studies of Lusardi and Mitchell (2007) and Chen et al. (2015a). Women are characterized by a significantly higher level of both pro-ecological behaviors and those related to the widely understood issue of energy saving (Białynicki-Birula et al., 2022). The research of Chen et al. (2015b) led to similar results, as while male students showed better knowledge, their attitude towards energy issues was less positive than female students who performed better in energy-conscious behaviors such as walking or cycling short distances. Additional gender differences in cognitive skills were attributed by Chen et al. (2015b) to the academically oriented nature of Taiwan's education system. As expected, boys performed better than girls in energy-related knowledge, especially in the scientific fundamentals of energy, which is consistent with research findings that secondary school students have higher interest and stronger self-efficacy in science than girls (Kang et al. 2019). However, Hayes (2001) showed that although the two sexes differ in scientific knowledge, this has little or no effect on environmental attitudes. In contrast, the present study and DeWaters and Powers (2011) showed that women had more positive attitudes than men regarding energy issues, which coincides with the perception that adolescent women are more "ecocentric" than men as found in a survey conducted in England among 1277 8th graders (Jenkins and Pell 2006). In addition to previous studies on energy literacy, Alp et al. (2008) showed statistically significant gender differences in attitudes towards the environment, with female students showing more positive attitudes than male students. Furthermore, studies have shown that girls demonstrate greater responsibility towards the environment than boys (Alp et al. 2008; Tikka et al., 2000). When explaining gender differences in environmental issues, structural and socialization-based theories are often used. Blocker and Eckberg (1997) focused on investigating how women's social status and stereotypes influenced their approach to environmental issues. They concluded that women tend to be more interested in environmental issues than men due to their social and structural position in society. Furthermore, Öztürk et al. (2013) argued that the difference between men's and women's attitudes towards environmental issues decreases when women's social status, economic power and trust in science increase. The fact that studies conducted in Germany, Norway, Greece and Spain have shown that higher total energy consumption can be observed in the case of men compared to women may be related to some extent to the level of awareness of both groups (Räty & Carlsson-Kanyama, 2010). In general, female students perform better

than male students, are more concerned about sustainable energy use, but male students are more familiar with energy-saving behaviors than female students (Bahrami & Mohammadi, 2021). It is obvious that gender-related research results are strongly influenced by the socio-political and economic environment experienced by respondents. An energy literacy assessment in Japan showed that female students scored higher than male students on the cognitive and self-efficacy subscales. Female students achieved higher mean scores than male students on three factors: environmental knowledge, awareness of consequences, and responsibility (Akitsu et al., 2017). Although Gambro & Switzky (1999) considered that exposure to science contributes to the level of knowledge of high school students about environmental issues, there is no difference in the number of science courses taken between genders in the compulsory education curriculum in lower secondary schools in Japan. However, it is noted that an interaction between knowledge of environmental issues and gender was found in terms of energy conservation.

2.2.3 Participation in environmental organizations and actions

The cultivation of environmental awareness and positive attitudes from pre-primary education age and into higher education levels is a determining factor for the development and adoption of energy-saving practices that can evolve and last throughout an individual's life (Osuntuyi & Lean, 2023; Ballantyne et al., 1998). Studies confirm the view that environmental knowledge and participation in environmental actions cause change in attitudes and behaviors (Akitsu et al., 2017). An individual's environmental action can take forms such as pro-environmental behavior where the individual tries to limit actions that cause environmental damage and various types of activism, individual or collective (Martono et al., 2024). An individual with environmental concerns and values is very likely to participate in pro-environmental actions (Cayolla 2023; Kountouris & Williams, 2023). Pro-environmental behaviours are influenced by an individual's internal value system, guilt and values, social norms, interaction with people who are concerned about environmental balance, and action in cooperation with others (Yue et al., 2020; Vicente-Molina et al., 2013; Diamantopoylos et al., 2003). Eco centric values and the high position of nature protection in a person's value system promote environmental action in contrast to anthropocentric values and views of human dominance over nature (Moshood et al., 2022). Environmental activism at a young age usually includes joining environmental groups and participating in actions aimed at protecting the environment (Ünal et al., 2018; De Leeuw et al., 2015). Environmental protection actions are often promoted on social networks by green influencers who provide information about a zero waste lifestyle (König & Maier, 2024; Yıldırım 2021). The exchange of opinions and information between group members pushes them to become part of the solution to the problem in various ways such as recycling, targeted consumption habits aimed at reducing the consumption of goods such as energy (Paco & Gouveia Rodrigues, 2016; Zsóka et al., 2013; Bartiaux, 2008). Knowledge about environmental problems such as climate change, biodiversity loss, marine pollution, carbon dioxide emissions and global warming leads to environmental action and responsible use of energy (Lee et al., 2019; Roczen et al., 2014). Understanding the impact of one's lifestyle on nature and activism is positively correlated with commitment to "green" behaviours and efforts to

reduce environmental footprint (Droz, 2022; Mackay et al., 2021). Environmental activism focuses on informing the public for decision-making, recycling, the use of environmentally friendly products, and the use of forms of energy with environmental criteria (Knupfer et al., 2023; Hassaniyan, 2021). However, mere participation in environmental organizations is not sufficient in itself to make a profound difference in students' knowledge or attitudes, especially if this participation is more formal than substantive, or that the organizations' actions are not sufficiently targeted to actively enhance children's knowledge and awareness. The duration and frequency of individuals' participation in actions as well as their degree of involvement in them affects their awareness of their desire to acquire knowledge and their awareness of energy issues (Martono et al., 2024; Lee et al., 2017; Chen et al., 2015a; Lay et al., 2013; Pe'er et al., 2007; Tikka et al., 2000).

3. Methodology

The target population of the current study consisted of students of the Attica region. The Attica region has seven secondary education directorates to which the questionnaires were distributed in person. The schools that participated in the study were randomly selected. A total of 50 mainstream schools participated. 9950 questionnaires were distributed and 6161 were returned, an acceptance rate of 61.9%. Before the start of the sampling, a pre-testing process was carried out in which a total of 100 students from all three grades of the high school took part. Modifications were made to parts of the questionnaire that presented difficulty in understanding for the students without altering the meaning of the items. The questionnaires were completed within the school timetable and one hour was allocated by each school for each grade. The students completed the questionnaire with a maximum completion time of 50 minutes under the supervision of the researchers and the class teacher. The identity of the sample is presented in Table 1.

Table 1. Distribution of students according to Gender and Grade

	Gender		**Grade**		
	Male	Female	7th	8th	9th
Number of Students	3.137	3.024	2.102	2.078	1.981
Percentage	50.92	49.08	34.12	33.73	32.15

The questionnaire contains closed-ended questions and five-point Likert scale items. It consists of a first part with demographic data, three parts with cognitive, affective and behavioral items and two parts with questions assessing students' environmental attitudes and life values.

To determine if there was significant difference in the students' energy literacy a) based on gender, Chi-Square test of independence and independent samples T-test analyses were used b) based on students' grade and c) based on their participation in an environmental organization, Chi-Square test of independence and Anova were applied. The analyses were applied at a predetermined significance level of 0.05.

4. Results

Students believe that they have moderate knowledge about energy (48.5%), a significant percentage believes that they are quite informed (29.1%), while fewer believe that they do not know much (16.8%) or that they know nothing (3%) or, conversely, that they know energy issues very well (2.6%). A large percentage believe that they are moderate energy consumers (44.1%), while several state that they sometimes (23.8%) or always (8.2%) try to save energy. On the contrary, approximately a quarter of students believe that they consume a significant amount (18.3%) or a large amount (5.6%) of energy (Figure 1).

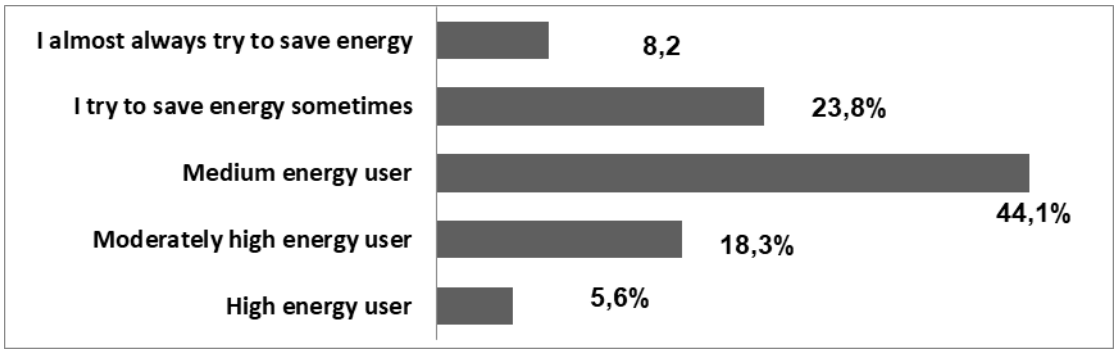

Figure 1. Students' beliefs about their energy usage

Students consider school (38.1%) as the main source of information on energy-related issues, followed by the internet (25.7%) and family and friends (25.3%) (Figure 2).

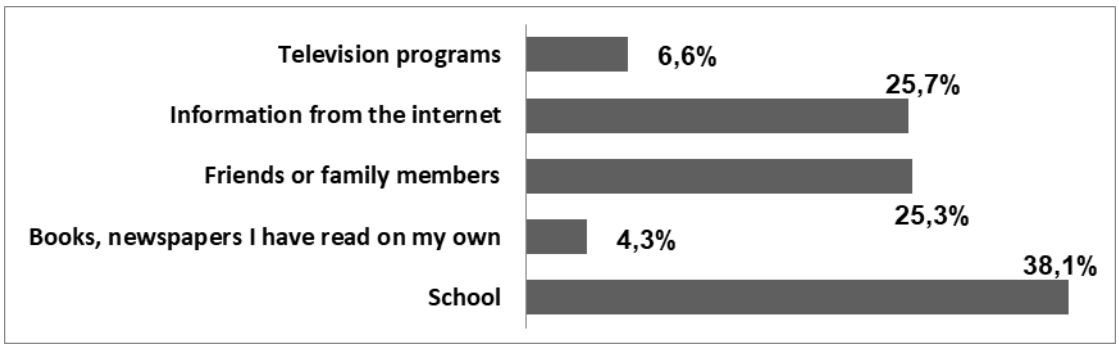

Figure 2. Students' main source of information on energy-related issues

More than half of students discuss energy saving practices with their family often (41.2%) or a lot (12%), while less than a quarter of students have discussed them very little (16%) or not at all (6.5%) (Figure 3).

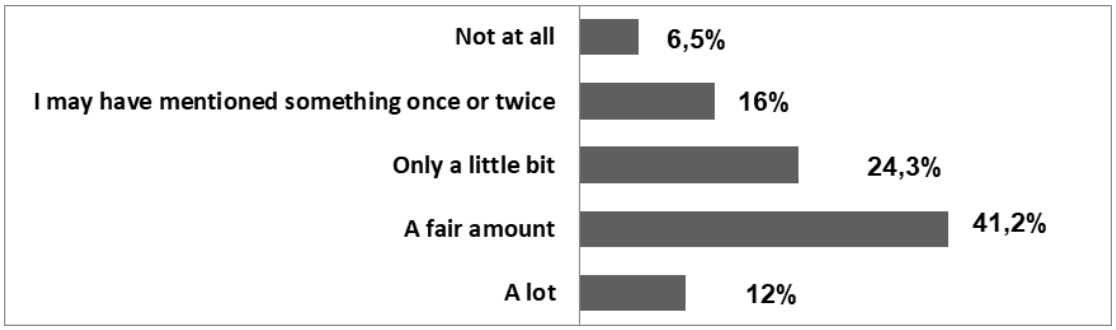

Figure 3. The frequency with which students discuss energy issues with their families

Students' attitudes and beliefs about energy are examined in 12 items. Students were placed on a series of issues that concern public opinion (figure 4). The majority of them believe that they can contribute to solving energy problems by working with others (strongly agree 21.3%, agree 47.4%). A total of 66.3% (strongly agree 17.4%, agree 48.9%) expressed the belief that they can contribute to solving energy problems by making appropriate energy-related choices and actions. They present environmentally friendly attitudes as they strongly disagree with the development of oil fields in areas protected by environmental laws (strongly disagree 28.8%, disagree 35.6%) and with the relaxation of laws in order to favor energy production (strongly disagree 24.9%, disagree 32.2%). They want to be informed about the operating costs and the resources used to manufacture an electrical device (strongly agree 20.6%, agree 41.3%). They do not believe that technology can replace the effort to conserve energy (strongly disagree 24.9%, disagree 32.2%) and therefore are strongly positive (strongly agree 20.6%, agree 41.3%) in the view that Greeks should conserve more energy (strongly agree 24.7%, agree 32.1%). They strongly disagree, cumulatively at a percentage of 83.3% (strongly disagree 45.5%, disagree 27.8) with the view that they do not need to worry about the consumption of electricity by lights and computers at school as this is responsible for the electricity bill. They do not show a high degree of agreement with the proposition that the way they use energy has no impact on the energy problem facing the country (strongly agree 24.7%, agree 32.1%). On the contrary, they strongly agree at a rate of 85.3% (strongly agree 58.2%, agree 27.1%) on energy saving and state that they would try harder to save if they had relevant knowledge (strongly agree 29.2%, agree 42%). As a consequence of this view, they believe at a cumulative rate of 73.4% (strongly agree 34%, agree 39.4%) that energy education should be an important part of the school curriculum.

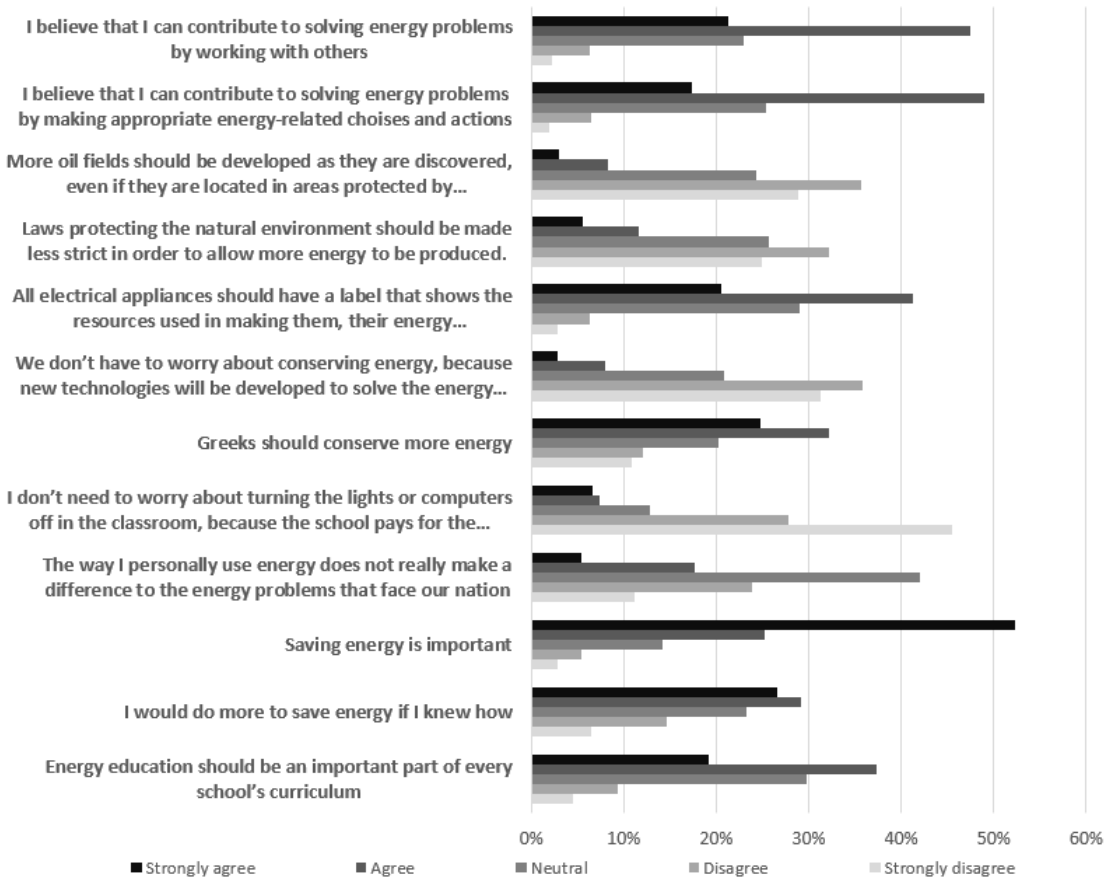

Figure 4. Students' attitudes

Students' attitudes and practices towards mainly energy issues were detected from their responses to statements (Figure 5). Students indicated a significant willingness to save energy by limiting their purchases (strongly agree 13.3%, agree 28.1%) while several indicated neutrality (31.8%) to this statement. Similar responses are noted for the statement "I am willing to encourage my family to buy energy efficient light bulbs" (strongly agree 18%, agree 27%). Students have a low level of agreement with the statement that their family buys energy efficient light bulbs (strongly agree 13.3%, agree 28.1%). On the contrary, they consider that they are willing to encourage their family to reduce energy consumption for heating (strongly agree 35%, agree 28.6%) and they report in a high percentage that their family does not consume energy for heating or cooling the house during the hours they are away from home (strongly agree 49%, agree 27.1%). They show a low degree of agreement (strongly agree 6.8%, agree 21.3%) and appear basically neutral (39.3%) in the view that many of their daily decisions are influenced by their thoughts about energy consumption. They turn off the computer when it is not being used (strongly agree 41.1%, agree 24%) and they turn off the lights when they leave a room (strongly agree 52.4%, agree 25.2%). The majority of students prefer to walk or ride a bike to travel short distances instead of asking for a ride in the car (strongly agree 26.6%, agree 29.1%) and believe that they are trying to save water (strongly agree 19.2%, agree 37.3%).

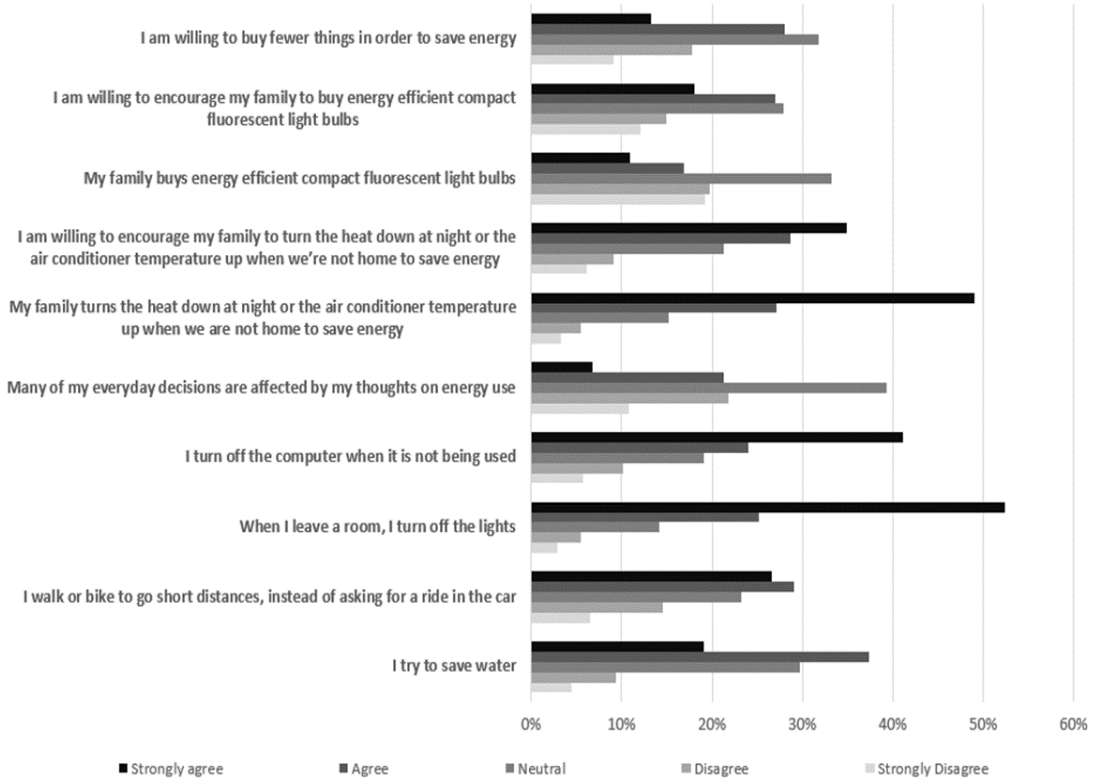

Figure 5. Students' behaviours

To determine if there was significant difference in the students' energy literacy based on gender, Chi-Square test of independence and independent samples T-test analyses were used. The statistical analysis revealed significant differences in the responses between boys and girls to many of the questions related to energy and the environment. The responses to the variables related to the understanding of electrical energy units, forms of energy, the definition and recognition of renewable energy sources and their forms and use in Greece presented significant statistical differences. For example, the percentage of students who chose solar radiation, biomass and bioethanol as a source of renewable energy was higher among girls compared to boys. Boys had higher error rates when choosing gasoline as a biofuel compared to girls, showing problematic understanding of energy concepts. Girls were more likely to choose answers related to reducing or reusing products, indicating a greater tendency towards environmentally sustainable behaviors.

To determine if there was significant difference in the students' energy literacy based on students' grade Chi-Square test of independence and ANOVA were applied. The results showed statistically significant correlations with many of the answers to the questions. Higher grade students had higher performance in the cognitive part. Specifically, in the questions concerning the units of energy measurement, the distinction between renewable and non-renewable energy sources and the concept of biomass, higher grade students scored higher. At the same time, seniors more often chose the correct answer to questions concerning the use of lignite in Greece, the impacts of nuclear energy and the causal relationship between global warming and the combustion of fossil fuels.

Chi-Square test of independence and ANOVA that were applied show no significant difference ii the students' energy literacy based on their participation in an environmental organization as they did not show any significant variation in students' responses in relation to this variable. Although some questions related to environmental action and renewable sources had slight variations, these were not statistically significant.

Cluster Analysis to identify energy literacy profiles and Latent Class Analysis (LCA) to identify latent groups of students with similar response patterns were applied. Redefinition of the three subscales based on the variety of responses, so as to retain only variables with sufficient variance was made. From this process three subscales emerged, a) knowledge subscale (14 items), b) affective subscale (5 items) and c) behaviour subscale (5 items). Based on mean scores and correlations, students are grouped into three meaningful classes:

Class 0 – Informed but Passive

Class 1 – Active and Sensitized

Class 2 – Moderately Informed and Inactive

The classes had statistically significant differences in terms of gender, grade, and student participation in environmental organizing (Table 2).

Table 2

	X^2	p value
Gender	28.49	< 0.001
Grade	11.30	= 0.023
Participation in an environmental organization	7.09	= 0.029

The three classes show differences in the three subscales of energy literacy (Table 3).

Table 3

Class	Name	Knowledge	Attitudes	Behaviours
0	Informed but Passive	High	Relatively low	Moderate/low
1	Active and Sensitized	Moderate	High	Active
2	Moderately Informed & Inactive	Moderate	Moderate	Limited

Class 0 has good theoretical knowledge of energy issues (i.e. nuclear power, coal, sun), but shows low awareness and levels of environmental action and engagement. This group shows limited activation. These are students who know about energy issues, but do not translate this knowledge into actions or attitudes. It consists mainly of boys and students from lower grades.

Class 1 shows increased ecological sensitivity and an active environmental attitude, even when its cognitive level is moderate. They show high environmental sensitivity. They are the "doers", not just the "knowers". They are likely to participate in environmental actions or are positively influenced by the school or family environment. In the gender analysis, this class included a higher percentage of girls, students with participation in environmental

organizations and older students.

Class 2 includes students with moderate knowledge, without strong ecological awareness, without substantial energy behavior and low participation in environmental organizations. They are not indifferent, but they do not show a willingness to be active, probably due to limited exposure to environmental stimuli. They constitute a "neutral" group that does not present a specific direction. As a group, it is "plastic" and depending on the influences it receives, it will move either towards substantial activation or towards inaction and indifference.

5. Discussion

More than half of the students discuss energy saving issues with their families which is consistent with previous studies (Aguirre-Bielschowsky et al., 2017; Alyousef & Varnham, 2010). The main source of information for the students is school, followed by the internet and their friends and family. Books and newspapers are a basic source of information for a very small percentage of students. These findings are in line with previous studies (Lee et al., 2015; Alghamdı & El-Hassan, 2019; Bahrami & Mohammadi 2021). Students present positive attitudes towards energy saving and pro-environmental behaviours. Energy waste is reprehensible while they want to participate in solving energy-related problems. They consider themselves responsible for their share of the energy problem and want to influence their family towards energy saving. At the same time, they wish to work collaboratively towards energy and environmental sustainability. They do not agree with the degradation of the natural environment in order to favour the production of energy, even of its so-called clean forms. These views are in line with the literature in which young people appear to have environmental anxiety, fuelled mainly by information sources such as the internet, the media and especially school (Niedzwiedz et al., 2025; Denault et al., 2024; Clayton et al., 2023; Kankawale & Niedzwiedz, 2023; Kubrak, 2020). For this reason, they have a negative view of energy waste and approve of collective action (Neas et al., 2022; Kuthe et al., 2019; Pearce et al., 2020). Contrary to Shapiro (2013) and the technology bias reported in our results, students do not believe that they can rely on technology to correct the effects of their wasteful energy use. The findings of this study do not also agree with previous studies according to which when the responsibility of paying the bill is not borne by an individual, this individual does not exhibit energy saving practices as students declare that they save energy at school even though it is the individual who is responsible for paying for the electricity (Brutscher, 2011; Dianshu et al., 2010). Students' statement that they could do more to save energy if they knew how to do so and their high level of agreement with the view that energy education should be an important part of the school curriculum are in line with studies that report that students, although concerned about energy issues, lack the knowledge, skills, and guidance to build energy-saving routines (Aguirre-Bielschowsky, 2017; Boudet et al., 2016; Fell & Chiu, 2014; Kopnina, 2011).

Gender-based differences in environmental education or awareness, are noted. Girls showed higher knowledge on renewable energy issues while boys showed problematic understanding of energy-related concepts. At the same time, girls showed greater pro-environmental

attitudes compared to boys. The results of the research are in line with previous research according to which girls show more positive attitudes than boys on energy issues, have a higher level of awareness on energy saving issues and are more eco-centric (Bialynicki-Birula et al., 2022; Alp et al., 2008; DeWaters & Powers, 2011; Jenkins & Pell, 2006). On the contrary, the findings of the study do not confirm other studies in which no differences between the two genders are observed or boys seem to have better performance in the cognitive subscale (Chen et al., 2015a; Chen et al., 2015b; Kang et al., 2019; Hayes, 2001) and in energy-saving behaviours (Bahrami & Mohammadi, 2021). This is logical as measurements of gender differences can be influenced by the social and political context in which the research takes place or the character of the country's education system (Akitsu et al., 2017; Chen et al., 2015b; Blocker & Eckberg, 1997; Öztürk et al., 2013).

The study implies a progressive strengthening of knowledge about energy with age, but also the effectiveness of school education on some key environmental issues. Students scored higher mainly on the cognitive subscale according to grade levels. Students, as they age, acquire higher abilities to process abstract schemas such as energy, mainly in high school where they enter the formal operational stage (Piaget, 2000). At the same time, the spiral structure of the Greek syllabus leads to repetition and consolidation of concepts (Boladola, 2018). The results reinforce the hypothesis that as the level of education increases, students acquire more in-depth knowledge and different attitudes towards energy and the environment. The results are similar to previous studies where older students performed better on all three subscales (DeWaters & Powers, 2011; Chen et al., 2015a; Akitsu et al., 2017). At the same time, the results contrast with studies in which age was not a determinant of energy knowledge (Lee et al., 2015) and reported that younger students had more awareness for energy saving than higher grade students (Aktamis 2011). Attitudes, emotional involvement and a sense of responsibility are important activating factors. Students who showed intense environmental action did not necessarily have high cognitive scores, but they had increased affective sensitivity. (Neas et al., 2022; Kuthe et al., 2019; Constantino, 2022; Schunk, 1989; Bandura & Schunk, 1981; Kazdin, 1979). The findings may indicate that mere participation in environmental organizations is not sufficient in itself to make a profound difference in students' knowledge or attitudes. Either that participation is more formal than substantive, or that the organizations' actions are not sufficiently targeted to actively enhance children's knowledge and awareness. Alternatively, the duration of participation or the frequency of involvement may differ, without being captured by the variable, thus influencing the results (Lee et al., 2017; Lay et al., 2013; Pe'er et al., 2007; Tikka et al., 2000).

Groups of students with similar response patterns were identified. The three classes into which the students were grouped indicate differences in energy literacy in the cognitive part, attitudes and behaviors. The typology of the three classes confirms the theory of energy literacy and the three pillars model (DeWaters & Powers, 2011, 2013). It shows that knowledge alone is not a predictive factor for attitudes and the adoption of energy sustainable behaviors by students. On the contrary, attitudes and sensitivity lead to action. This is consistent with studies that report that positive attitudes of young people towards energy conservation do not translate into corresponding behaviors, although attitudes and behaviors

are more strongly correlated than knowledge with behaviors (DeWaters & Powers, 2011, 2013; Aguirre-Bielschowsky, 2017; Akitsu et al., 2017; Boudet et al., 2016; Fell & Chiu, 2014; Kopnina, 2011; Suryana et al., 2020). Class 1, which is characterized by environmental empathy and action, is considered to have the most suitable background to receive educational interventions to change students' behaviour and adopt energy-saving routines. The studies that make up the literature on energy literacy show significant differences between them. It thus proves that energy literacy is a multifactorial system with many degrees of freedom and low predictability. However, all studies conclude on the ability of education, especially formal education, to guide students towards sustainable energy behaviours with appropriate techniques and approaches.

6. Conclusions and Policy Implications

Energy literacy is a complex multidimensional concept influenced by a series of factors. In Greece, limited attention has been paid to the holistic nature of the term. Approaches to the concept are fragmented, strictly limited to specific teaching subjects with a defined teaching method. There is no continuity of knowledge about energy as students move up grades. Knowledge should present a holistic character. This character is thwarted when students start high school as this is characterized by its clear orientation towards public university exams. The consequence of that fact is that the energy literacy of Greek high school students is largely determined by factors outside the educational process such as their beliefs and values, social conditions, family environment, mass media, their experiences, etc. Gender and age are associated with the energy literacy of Greek students, confirming the results of previous studies. At the same time, the consistency of the results with other research according to which students' attitudes, in contrast to knowledge, show a significant correlation with their behaviour, raises thoughts about the educational process that would be appropriate for the promotion of energy literacy. The reform of curricula should include teaching practices that are not the usual way of teaching in the world of the Greek educational system. These practices should invest in attitudes and values. The emotional dimension such as environmental concern, sense of responsibility and personal interest seems to influence energy-responsible actions to a greater extent. The results also showed that students with pro-environmental behaviours and active in energy saving efforts do not necessarily have the highest cognitive background. Therefore, it becomes clear that the sterile transmission by the school and the memorization by students of information of strictly academic interest does not promote energy literacy. On the contrary, educational strategies are needed that lead students to sustainable behaviors. Policy implications suggest a rebuilt of energy education, aiming not only at cognitive cultivation but also at the emotional empowerment and activation of students. Educational interventions must incorporate value-based, participatory and experiential approaches, so that students internalize sustainable energy as an element of their personal and social responsibility. Finally, institutionally strengthening students' participation in school environmental clubs, cooperation with environmental organizations and the establishment of voluntary actions are strategies that can significantly enhance their energy involvement. In summary, we can identify the following six axes that will improve students' energy literacy, i) emphasis on cultivating attitudes and values. Creation of energy education

groups that will operate after school hours, ii) action-oriented teaching practices. Voluntary participation in actions organized by the local community, iii) approaching knowledge and practice based on the age and level of intellectual development of the students and, where possible, based on gender, as students in older classes and girls present stronger pro-environmental attitudes, iv) organization and participation of the school in environmental actions and information and energy saving actions within the social context that encompasses the school unit, cultivating extroversion for the school community, v) development and adoption of energy literacy assessment tools so that additional interventions can be carried out where necessary and vi) the development of a teaching subject oriented to energy issues that constitutes an integral part of the primary and secondary education program.

Students are the current and future consumer base of a society. Societies that are oriented towards sustainability must have members with attitudes, values and behaviours that promote the proper use of energy. This can ensure energy sufficiency and security for a society, which is a requirement in today's era. Cultivating attitudes and behaviours brings to the forefront education and the effort to transform it to serve the demands of modern society that satisfy the 7th SDG, namely ensuring access to affordable, reliable, sustainable and modern energy (UN, 2023).

Acknowledgments

Not applicable

Authors contributions

Sample: Mr. K Kougias and Prof. E. Sardianou were responsible for study design and revising. Mr K. Kougias was responsible for data collection and statistical analysis. Mr K. Kougias drafted the manuscript and Prof. E. Sardianou revised it. All authors read and approved the final manuscript.

Funding

Not applicable

Competing interests

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.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Macrothink Institute.

The journal’s policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

References

Aguirre-Bielschowsky, I., Lawson, R., Stephenson, J., & Todd, S. (2017). Energy literacy and agency of New Zealand children. *Environmental Education Research, 23*(6), 832-854.

Akitsu, Y., Ishihara, K. N., Okumura, H., & Yamasue, E. (2017). Investigating Energy Literacy and Its Structural Model for Lower Secondary Students in Japan. *International Journal of Environmental and Science Education, 12*(5), 1067-1095.

Aktamis, H. (2011). Determining energy saving behavior and energy awareness of secondary school students according to socio-demographic characteristics. *Educational Research and Reviews, 6*(3), 243.

Alghamdı, A. K. H., & El-Hassan, W. S. (2019). Saudi undergraduate students' needs of pedagogical education for energy literacy. *Journal of Turkish Science Education, 16*(4), 521-537.

Alp, E., Ertepinar, H., Tekkaya, C., & Yilmaz, A. (2008). A survey on Turkish elementary school students' environmental friendly behaviours and associated variables. *Environmental education research, 14*(2), 129-143.

Alyousef, Y., & Varnham, A. (2010). Saudi Arabia's National Energy Efficiency Programme: description, achievements and way forward. *International journal of low-carbon technologies, 5*(4), 291-297.

Armaroli, N., & Balzani, V. (2007). The future of energy supply: challenges and opportunities. *Angewandte Chemie International Edition, 46*(1-2), 52-66.

Ayata, S., Oylumluoglu, G., & Alpaslan, M. M. (2024). Contributions of Epistemological Beliefs on Energy Literacy in Lower-Secondary School Students in Turkey. *Journal of Baltic Science Education, 23*(3), 421-431.

Bahrami, S., & Mohammadi, Y. (2021). Assessing energy literacy of Iranian ninth-grade students. *Journal of Turkish Science Education, 18*(4), 707-731.

Ballantyne, R., Connell, S., & Fien, J. (1998). Students as catalysts of environmental change: A framework for researching intergenerational influence through environmental education. *Environmental education research, 4*(3), 285-298.

Bandura, A., & Schunk, D. H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of personality and social psychology, 41*(3), 586.

Barrett, P. (2022). How food and energy are driving the global inflation surge. *IMF. Sept, 12.*

Barrow, L. H., & Morrisey, J. T. (1987). Ninth-grade students' attitudes toward energy: A comparison between Maine and New Brunswick. The Journal of Environmental Education, 18(3), 15-21.

Bartiaux, F. (2008). Does environmental information overcome practice compartmentalisation and change consumers' behaviours?. *Journal of cleaner production, 16*(11), 1170-1180.

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science education, 91*(3), 347-370.

Białynicki-Birula, P., Makieła, K., & Mamica, Ł. (2022). Energy literacy and its determinants among students within the context of public intervention in Poland. *Energies, 15*(15), 5368.

Blasch, J., Boogen, N., Daminato, C., & Filippini, M. (2018). Empower the consumer! Energy-related financial literacy and its socioeconomic determinants. *Economics Working Paper Series, 18*.

Blocker, T. J., & Eckberg, D. L. (1997). Gender and environmentalism: Results from the 1993 general social survey. *Social Science Quarterly*, 841-858.

Bodzin, A. M., Fu, Q., Peffer, T. E., & Kulo, V. (2013). Developing energy literacy in US middle-level students using the geospatial curriculum approach. *International Journal of Science Education, 35*(9), 1561-1589.

Boladola, B. R. (2018). Memory Retention and Retrieval in K–12 Spiral Progression Approach in Science: A Curriculum Issue Analysis. *Silliman Journal, 59*(1).

Borisov, L. (2024). Relationship between energy and food prices in the euro area. *Baltic Journal of Economic Studies, 10*(3), 36-41.

Boudet, H., Ardoin, N. M., Flora, J., Armel, K. C., Desai, M., & Robinson, T. N. (2016). Effects of a behaviour change intervention for Girl Scouts on child and parent energy-saving behaviours. *Nature Energy, 1*(8), 1-10.

Brounen, D., Kok, N., & Quigley, J. M. (2013). Energy literacy, awareness, and conservation behavior of residential households. *Energy Economics, 38*, 42-50.

Brundtland, G. H. (1987). Our common future world commission on environment and developement.

Brutscher, P. B. (2011). Payment matters?-an exploratory study into the pre-payment electricity metering.

Cayolla, R., Escadas, M., McCullough, B. P., Biscaia, R., Cabilhas, A., & Santos, T. (2023). Does pro-environmental attitude predicts pro-environmental behavior? Comparing sustainability connection in emotional and cognitive environments among football fans and

university students. *Heliyon, 9*(11).

Chandrasenan, A. F. V. D. Identifying the Multidimensional Energy Literacy Levels of Elementary School Students of Kerala, India: A Measure of Knowledge, Attitude and Behaviour. *eNergetics 2022*, 77.

Chen, K. L., Liu, S. Y., & Chen, P. H. (2015a). Assessing multidimensional energy literacy of secondary students using contextualized assessment. *International Journal of Environmental and Science Education, 10*(2), 201-218.

Chen, S. J., Chou, Y. C., Yen, H. Y., & Chao, Y. L. (2015b). Investigating and structural modeling energy literacy of high school students in Taiwan. Energy Efficiency, 8, 791-808.

Clayton, S. D., Pihkala, P., Wray, B., & Marks, E. (2023). Psychological and emotional responses to climate change among young people worldwide: Differences associated with gender, age, and country. *Sustainability, 15*(4), 3540.

Constantino, S. M., Sparkman, G., Kraft-Todd, G. T., Bicchieri, C., Centola, D., Shell-Duncan, B., ... & Weber, E. U. (2022). Scaling up change: A critical review and practical guide to harnessing social norms for climate action. *Psychological science in the public interest, 23*(2), 50-97.

Das, R. R., & Richman, R. (2022). The development and application of a public energy literacy instrument. *Canadian Journal of Science, Mathematics and Technology Education, 22*(1), 42-67.

De Leeuw, A., Valois, P., Ajzen, I., & Schmidt, P. (2015). Using the theory of planned behavior to identify key beliefs underlying pro-environmental behavior in high-school students: Implications for educational interventions. *Journal of environmental psychology, 42*, 128-138.

Denault, A. S., Bouchard, M., Proulx, J., Poulin, F., Dupéré, V., Archambault, I., & Lavoie, M. D. (2024). Predictors of Pro-Environmental Behaviors in Adolescence: A Scoping Review. *Sustainability, 16*(13), 5383.

DeWaters, J., Powers, S., & Graham, M. (2007, June). Developing an energy literacy scale. In *2007 Annual Conference & Exposition* (pp. 12-485).

DeWaters, J., & Powers, S. (2008, October). Energy literacy among middle and high school youth. In *2008 38th Annual Frontiers in Education Conference* (pp. T2F-6). IEEE.

DeWaters, J. E., & Powers, S. E. (2011). Energy literacy of secondary students in New York State (USA): A measure of knowledge, affect, and behavior. *Energy policy, 39*(3), 1699-1710.

DeWaters, J., & Powers, S. (2013). Establishing measurement criteria for an energy literacy questionnaire. *The Journal of Environmental Education, 44*(1), 38-55.

Dianshu, F., Sovacool, B. K., & Vu, K. M. (2010). The barriers to energy efficiency in China: Assessing household electricity savings and consumer behavior in Liaoning Province. *Energy Policy, 38*(2), 1202-1209.

Dijkstra, E. M., & Goedhart, M. J. (2012). Development and validation of the ACSI: Measuring students' science attitudes, pro-environmental behaviour, climate change attitudes and knowledge. *Environmental Education Research, 18*(6), 733-749.

Droz, L. (2022). Challenging harmony to save nature?: Environmental activism and ethics in Taiwan and Japan. *International Journal for Crime, Justice and Social Democracy, 11*(1), 58-70.

Faia, R., Faria, P., & Vale, Z. (2025). Optimal energy management with discomfort calculation in residential buildings considering load shifting and home battery storage system. *Sustainable Energy, Grids and Networks, 41*, 101624.

Fell, M. J., & Chiu, L. F. (2014). Children, parents and home energy use: Exploring motivations and limits to energy demand reduction. *Energy Policy, 65*, 351-358.

Gambro, J. S., & Switzky, H. N. (1999). Variables associated with American high school students' knowledge of environmental issues related to energy and pollution. *The Journal of Environmental Education, 30*(2), 15-22.

Gołębiowska, B. (2020). Energy literacy in Poland. *Economics and Environment, 73*(2), 23-23.

Halkos, G., & Gkampoura, E. C. (2021). Where do we stand on the 17 Sustainable Development Goals? An overview on progress. *Economic analysis and policy, 70*, 94-122.

Hasanah, A., Sahlani, L., Zuhri, M. T., Kholifah, N., & Nurtanto, M. (2023). A systematic review of energy literacy programs at primary and middle schools. *Pegem Journal of Education and Instruction, 13*(1), 145-155.

Hassaniyan, A. (2021). The environmentalism of the subalterns: A case study of environmental activism in Eastern Kurdistan/Rojhelat. Local Environment, 26(8), 930-947.

Hayes, B. C. (2001). Gender, scientific knowledge, and attitudes toward the environment: A cross-national analysis. *Political research quarterly, 54*(3), 657-671.

Hermann, M., Pentek, T., & Otto, B. (2016, January). Design principles for industrie 4.0 scenarios. In *2016 49th Hawaii international conference on system sciences (HICSS)* (pp. 3928-3937). IEEE.

Hidalgo-Crespo, J., Coello-Pisco, S., Reyes-Venegas, H., Bermeo-Garay, M., Amaya, J. L., Soto, M., & Hidalgo-Crespo, A. (2022). Understanding citizens' environmental concern and their pro-environmental behaviours and attitudes and their influence on energy use. *Energy Reports, 8,* 103-109.

Horkheimer, M. (1972). Traditional and critical theory. Critical theory: *Selected essays, 188*(243), 1-11.

Holden, C. C., & Barrow, L. H. (1984). Validation of the test of energy concepts and values for high school. *Journal of Research in Science Teaching, 21*(2), 187-196.

Jaber, J. O., Awad, W., Rahmeh, T. A., Alawin, A. A., Al-Lubani, S., Dalu, S. A., ... & Al-Bashir, A. (2017). Renewable energy education in faculties of engineering in Jordan: Relationship between demographics and level of knowledge of senior students'. *Renewable and Sustainable Energy Reviews, 73*, 452-459.

Jenkins, E. W., & Pell, R. G. (2006). "Me and the environmental challenges": A survey of English secondary school students' attitudes towards the environment. *International Journal of science education, 28*(7), 765-780.

Kalmi, P., Trotta, G., & Kažukauskas, A. (2021). Energy-related financial literacy and electricity consumption: Survey-based evidence from Finland. *Journal of Consumer Affairs, 55*(3), 1062-1089.

Kang, J., Hense, J., Scheersoi, A., & Keinonen, T. (2019). Gender study on the relationships between science interest and future career perspectives. *International Journal of Science Education, 41*(1), 80-101.

Kankawale, S. M., & Niedzwiedz, C. L. (2023). Eco-anxiety among children and young people: systematic review of social, political, and geographical determinants. *MedRxiv*, 2023-12.

Karpudewan, M., Ponniah, J., & Md. Zain, A. N. (2016). Project-based learning: An approach to promote energy literacy among secondary school students. *The Asia-Pacific Education Researcher, 25*, 229-237.

Kazdin, A. E. (1979). Imagery elaboration and self-efficacy in the covert modeling treatment of unassertive behavior. *Journal of Consulting and Clinical Psychology, 47*(4), 725.

Khuc, Q. V., Tran, M., Nguyen, T., Thinh, N. A., Dang, T., Tuyen, D. T., ... & Dat, L. Q. (2023). Improving energy literacy to facilitate energy transition and nurture environmental culture in Vietnam. *Urban Science, 7*(1), 13.

Knupfer, H., Neureiter, A., & Matthes, J. (2023). From social media diet to public riot? Engagement with "greenfluencers" and young social media users' environmental activism. *Computers in Human Behavior, 139*, 107527.

König, S., & Maier, E. (2024). Preaching to the choir: Do green influencers make a difference?. *Journal of cleaner production, 447*, 141449.

Kopnina, H. (2011). Kids and cars: Environmental attitudes in children. *Transport Policy, 18*(4), 573-578.

Kountouris, Y., & Williams, E. (2023). Do protests influence environmental attitudes? Evidence from Extinction Rebellion. *Environmental Research Communications, 5*(1), 011003.

Kubrak, T. (2020). Impact of films: Changes in young people's attitudes after watching a movie. *Behavioral sciences, 10*(5), 86.

Kuhn, D. J. (1979). Study of the Attitudes of Secondary School Students toward

Energy-Related Issues. *Science Education, 63*(5), 609-20.

Kumar, N. (2019). *A model-based clustering approach for analyzing energy-related financial literacy and its determinants* (No. 19/312). Economics Working Paper Series.

Kumari, N., Solanki, C. S., & Kumar, A. (2025). Responsible energy production and consumption: improving knowledge, attitude and behaviour through energy literacy training in India. *Climate Policy*, 1-15.

Kuthe, A., Keller, L., Körfgen, A., Stötter, H., Oberrauch, A., & Höferl, K. M. (2019). How many young generations are there?–A typology of teenagers' climate change awareness in Germany and Austria. *The Journal of Environmental Education*, 50(3), 172-182.

Lay, Y. F., Khoo, C. H., Treagust, D. F., & Chandrasegaran, A. L. (2013). Assessing Secondary School Students' Understanding of the Relevance of Energy in Their Daily Lives. *International Journal of Environmental and Science Education, 8*(1), 199-215.

Lawrenz, F., & Dantchik, A. (1985). Attitudes toward Energy among Students in Grades 4, 7 and High School. *School Science and Mathematics, 85*(3), 189-202.

Leal Filho, W., Manolas, E., & Pace, P. (2015). The future we want: Key issues on sustainable development in higher education after Rio and the UN decade of education for sustainable development. *International Journal of Sustainability in Higher Education, 16*(1), 112-129.

Lee, L. S., Chang, L. T., Lai, C. C., Guu, Y. H., & Lin, K. Y. (2017). Energy literacy of vocational students in Taiwan. *Environmental Education Research, 23*(6), 855-873.

Lee, L. S., Lee, Y. F., Altschuld, J. W., & Pan, Y. J. (2015). Energy literacy: Evaluating knowledge, affect, and behavior of students in Taiwan. *Energy Policy, 76*, 98-106.

Lee, L. S., Lee, Y. F., Wu, M. J., & Pan, Y. J. (2019). A study of energy literacy among nursing students to examine implications on energy conservation efforts in Taiwan. *Energy Policy, 135*, 111005.

Lowan-Trudeau, G., & Fowler, T. A. (2022). Towards a theory of critical energy literacy: The Youth Strike for Climate, renewable energy and beyond. *Australian Journal of Environmental Education, 38*(1), 58-68.

Lusardi, A., & Mitchell, O. S. (2007). Baby boomer retirement security: The roles of planning, financial literacy, and housing wealth. *Journal of monetary Economics, 54*(1), 205-224.

Mackay, C. M., Cristoffanini, F., Wright, J. D., Neufeld, S. D., Ogawa, H. F., & Schmitt, M. T. (2021). Connection to nature and environmental activism: Politicized environmental identity mediates a relationship between identification with nature and observed environmental activist behaviour. *Current Research in Ecological and Social Psychology, 2*, 100009.

Martins, A., Madaleno, M., & Dias, M. F. (2020a). Energy literacy: What is out there to know?. *Energy Reports, 6,* 454-459.

Martins, A., Madaleno, M., & Dias, M. F. (2020b). Energy literacy assessment among Portuguese university members: Knowledge, attitude, and behavior. Energy Reports, 6, 243-249.

Martono, S., Prajanti, S. D. W., Yulianto, A., Wijaya, A. P., & Dwiningrum, S. I. A. (2024). Environmental Activism: Analyzing the Attitudes of Eco-Friendly Consumers. *Journal of Ecohumanism, 3*(7), 2298-2308.

Moshood, T. D., Nawanir, G., Mahmud, F., bin Ahmad, M. H., Mohamad, F., & AbdulGhani, A. (2022). The plastic of the future: determinants for switching intention from synthetic to biodegradable plastics among the young consumers. *Journal of Social Marketing, 13*(1), 121-148.

Neas, S., Ward, A., & Bowman, B. (2022). Young people's climate activism: A review of the literature. *Frontiers in Political Science, 4*, 940876.

Niedzwiedz, C. L., Olsen, J. R., Rizeq, J., Afework, T., Hill-Harding, C. K., Shaw, R. J., ... & Papies, E. K. (2025). Coming to terms with climate change: a glossary for climate change impacts on mental health and well-being. *J Epidemiol Community Health, 79*(4), 295-301.

Nieto, A. M., & Saiz, C. (2011). Skills and dispositions of critical thinking: are they sufficient?. *Anales de psicología, 27*(1), 202-209.

Osuntuyi, B. V., & Lean, H. H. (2023). Environmental degradation, economic growth, and energy consumption: The role of education. *Sustainable Development, 31*(2), 1166-1177.

Öztürk, G., Tüzün, Ö. Y., & Teksöz, G. (2013). Exploring environmental literacy through demographic variables. Ilkogretim Online, 12(4).

Paço, A., & Gouveia Rodrigues, R. (2016). Environmental activism and consumers' perceived responsibility. *International Journal of Consumer Studies, 40*(4), 466-474.

Pearce, H., Hudders, L., & Van de Sompel, D. (2020). Young energy savers: Exploring the role of parents, peers, media and schools in saving energy among children in Belgium. *Energy Research & Social Science, 63*, 101392.

Pe'er, S., Goldman, D., & Yavetz, B. (2007). Environmental literacy in teacher training: Attitudes, knowledge, and environmental behavior of beginning students. *The journal of environmental education, 39*(1), 45-59.

Piaget, J. (2000). Piaget's theory of cognitive development. Childhood cognitive development: *The essential readings, 2*(7), 33-47.

Poimenidis, D., & Papavasileiou, V. (2021). Primary school students' cognitive awareness on bicycling as energy literacy in the context of education for sustainability. *Journal of Language and Education Policy, 2*(4), 14-21.

Pradana, N. L., Kesmawan, A. P., & Maharani, S. (2019). Energy literacy-based learning activities on female students. *International Journal of Scientific & Technology Research, 8*, 1711-15.

Ramcilovic-Suominen, S., & Pülzl, H. (2018). Sustainable development–a 'selling point'of the emerging EU bioeconomy policy framework?. *Journal of cleaner production, 172*, 4170-4180.

Rao, N. D., & Wilson, C. (2022). Advancing energy and well-being research. *Nature Sustainability, 5*(2), 98-103.

Räty, R., & Carlsson-Kanyama, A. (2010). Energy consumption by gender in some European countries. *Energy policy, 38*(1), 646-649.

Rets, I., Whitelock, D., Edwards, C., Perryman, L. A., & Goshtasbpour, F. (2024). Energising the Energy Literacy Debate for Environmental Education: Exploring Citizens' Interest Levels, Knowledge Gaps and Individual Differences. *Australian Journal of Environmental Education*, 40(4), 740-757.

Rockefeller, S. (2010, November). Challenges and opportunities facing the Earth Charter initiative. *In Keynote Address at the Conference on an Ethical Framework for a Sustainable World, Ahmedabad, 1-3 November.*

Roczen, N., Kaiser, F. G., Bogner, F. X., & Wilson, M. (2014). A competence model for environmental education. *Environment and Behavior, 46*(8), 972-992.

Sandberg, M., Klockars, K., & Wilén, K. (2019). Green growth or degrowth? Assessing the normative justifications for environmental sustainability and economic growth through critical social theory. *Journal of Cleaner Production, 206*, 133-141.

Schunk, D. H. (1989). Self-efficacy and achievement behaviors. *Educational psychology review, 1*, 173-208.

Schweiger, G., Eckerstorfer, L. V., Hafner, I., Fleischhacker, A., Radl, J., Glock, B., ... & Corcoran, K. (2020). Active consumer participation in smart energy systems. *Energy and Buildings, 227*, 110359.

Seyedabadi, E. S., Rasouli, S. E., & Salimi, L. (2024). Designing an Energy Literacy Curriculum Model with a Climate Change Approach in the Iranian Elementary Education System. *International Journal of Education and Cognitive Sciences, 5*(2), 91-100

Shapiro, S. (2013). Poor people, poor planet: The psychology of how we harm and heal humanity and earth. In *Toward a Socially Responsible Psychology for a Global Era* (pp. 231-254). New York, NY: Springer New York.

Sovacool, B. K., & Blyth, P. L. (2015). Energy and environmental attitudes in the green state of Denmark: Implications for energy democracy, low carbon transitions, and energy literacy. *Environmental Science & Policy, 54*, 304-315.

Steg, L., Perlaviciute, G., & Van der Werff, E. (2015). Understanding the human dimensions of a sustainable energy transition. *Frontiers in psychology, 6*, 805.

Stylos, G., Gavrilakis, C., Goulgouti, A., & Kotsis, K. T. (2023). Investigating energy literacy of pre-service primary school teachers in Greece. *Interdisciplinary Journal of Environmental*

and Science Education, 19(4), e2318.

Suryana, T. G. S., Setyadin, A. H., Samsudin, A., & Kaniawati, I. (2020, February). Assessing multidimensional energy literacy of high school students: an analysis of rasch model. In *Journal of Physics: Conference Series* (Vol. 1467, No. 1, p. 012034). IOP Publishing.

Szczygielski, J. J., Charteris, A., Obojska, L., & Brzeszczyński, J. (2024). What does energy price uncertainty reveal about the global energy crisis?. *International Review of Financial Analysis*, 103838.

Thompson, M. J. (2016). The domestication of critical theory. Rowman & Littlefield.

Tikka, P. M., Kuitunen, M. T., & Tynys, S. M. (2000). Effects of educational background on students' attitudes, activity levels, and knowledge concerning the environment. *The journal of environmental education, 31*(3), 12-19.

Ulussever, T., Kartal, M. T., & Kılıç Depren, S. (2025). Effect of income, energy consumption, energy prices, political stability, and geopolitical risk on the environment: evidence from GCC countries by novel quantile-based methods. *Energy & Environment, 36*(2), 979-1004.

Ünal, A. B., Steg, L., & Gorsira, M. (2018). Values versus environmental knowledge as triggers of a process of activation of personal norms for eco-driving. *Environment and behavior, 50*(10), 1092-1118.

United Cities & Local Governments. (2010). *Culture: fourth pillar of sustainable development*. United Cities and Local Governments (UCLG) Policy Statement.

United Nations Department of Economic and Social Affairs. (2023). *The sustainable development goals report 2023*: Special edition. UN.
https://www.un.org/sustainabledevelopment/energy/

US Department of Energy. (2017). *Energy Literacy: Essential principles and fundamental concepts for Energy Education*.
https://www.energy.gov/energysaver/energy-literacy-essential-principles-energy-education

Van den Broek, K. L. (2019). Household energy literacy: A critical review and a conceptual typology. *Energy Research & Social Science, 57*, 101256.

Van der Horst, D., Harrison, C., Staddon, S., & Wood, G. (2016). Improving energy literacy through student-led fieldwork–at home. *Journal of Geography in Higher Education, 40*(1), 67-76.

Van Ruijven, B. J., De Cian, E., & Sue Wing, I. (2019). Amplification of future energy demand growth due to climate change. *Nature communications, 10*(1), 2762.

Varghese, A. F., & Chandrasenan, D. (2022, September). Energy Literacy Scale (ELS): Validated Survey Instrument to Measure Energy Knowledge, Attitude, and Behaviour. In *International Conference on Energy and Environment Research* (pp. 793-800). Cham: Springer Nature Switzerland.

Vicente-Molina, M. A., Fernández-Sáinz, A., & Izagirre-Olaizola, J. (2013). Environmental knowledge and other variables affecting pro-environmental behaviour: comparison of university students from emerging and advanced countries. *Journal of Cleaner Production, 61*, 130-138.

Vlachogianni, T., & Valavanidis, A. (2013). Energy and environmental impact on the biosphere energy flow, storage and conversion in human civilization. *American Journal of Educational Research, 1*(3), 68-78.

Wang, C., Zhang, X., Xiong, H., & Guo, C. (2023). Distributed shared energy storage scheduling based on optimal operating interval in generation-side. *Sustainable Energy, Grids and Networks, 34*, 101026.

Yeh, S. C., Huang, J. Y., & Yu, H. C. (2017). Analysis of energy literacy and misconceptions of junior high students in Taiwan. *Sustainability, 9*(3), 423.

Yıldırım, S. (2021). Do green women influencers spur sustainable consumption patterns? Descriptive evidences from social media influencers. *Ecofeminism and Climate Change, 2*(4), 198-210.

York, R. (2016). Decarbonizing the energy supply may increase energy demand. *Sociology of development, 2*(3), 265-272.

Yue, B., Sheng, G., She, S., & Xu, J. (2020). Impact of consumer environmental responsibility on green consumption behavior in China: The role of environmental concern and price sensitivity. *Sustainability, 12*(5), 2074.

Zsóka, Á., Szerényi, Z. M., Széchy, A., & Kocsis, T. (2013). Greening due to environmental education? Environmental knowledge, attitudes, consumer behavior and everyday pro-environmental activities of Hungarian high school and university students. *Journal of cleaner production, 48*, 126-138.