Australian Journal of Environmental Education (2024), 1–18
doi:10.1017/aee.2024.37

CAMBRIDGE UNIVERSITY PRESS

ARTICLE

Energising the Energy Literacy Debate for Environmental Education: Exploring Citizens' Interest Levels, Knowledge Gaps and Individual Differences

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(Received 06 February 2024; revised 05 August 2024; accepted 05 August 2024)

Abstract

Energy literacy can empower individuals to make informed decisions about energy use. However, the level of public interest in learning about energy-related topics remains uncertain, and there is a dearth of research exploring energy literacy-related knowledge gaps. This mixed-methods study aimed to address those issues. A survey of 3,843 citizens from four European countries revealed that most citizens have only a moderate interest in learning about energy. Age, gender, educational level, income level, living situation and environmental attitudes appear to have a significant effect on individuals' interests. The study identified key knowledge demand areas regarding saving energy and reducing costs, becoming self-sufficient in energy production and cooperating with others for more efficient energy use. The findings indicate that engagement with energy-related topics could be improved by considering affective factors such as individual interest. The study also reveals a need for greater interdisciplinarity in energy research.

Keywords: Climate emergency; energy education; energy literacy; interest in learning; knowledge demand; mixed methods

Introduction

Climate change is "the defining crisis of our time" (The UN Refugee Agency, 2020) and is progressing more quickly than feared. Yet, as a society, we seem unable to respond to the climate crisis. Some experts diagnose this as our collective failure to learn: failure to learn to live with planetary limits.

Evidence suggests that individuals who are more aware of their daily choices, such as energy-related decisions, can better manage their energy consumption, thereby contributing to climate change mitigation (e.g. Cordero *et al.*, 2020). However, a number of studies report overall low energy literacy levels among people. For example, Sovacool and Blyth (2015) found that most Danish households did not know which devices used the most energy and less than 4% of the respondents answered all energy literacy questions correctly. Similarly, the nationwide study in Australia revealed that most householders were confused about energy issues (University of Queensland, 2019). The current prevailing top-down approach to energy provision, which largely excludes the public from network planning, further exacerbates the problem of low energy literacy levels among people (Snow *et al.*, 2022).

Energy literacy is defined as an understanding of the nature and role of energy in the world and in everyday life and the ability to apply this understanding (U.S. Department of Energy, 2017). In this definition, an energy-literate person is someone who:

(a) can trace energy flows and understand energy systems; (b) knows their energy usage, purposes and sources; (c) can assess the credibility of energy information; (d) can communicate meaningfully about energy; (e) can make informed energy decisions based on impacts and consequences; and (f) continues to learn about energy throughout life.

Most energy literacy frameworks feature three dimensions: cognitive (knowledge of energy topics), behavioural (appropriate intentions/behaviours) and affective (sensitivity and attitude towards energy topics) (Cotton *et al.*, 2021; Martins *et al.*, 2020). An affective variable often overlooked in energy literacy frameworks is individuals' interests in learning about energy-related topics (Martins *et al.*, 2020). It represents the extent to which individuals value information and/or knowledge about domestic energy use and conservation and have the desire to acquire more knowledge and be involved in activities related to the topic. A systematic investigation of interest regarding energy can inform energy literacy research and practice, as interest is found to endure over the long term and influence individuals' orientations to action (Hidi & Renninger, 2006).

An increasing number of scholars call for a stronger focus in research and practice on people's learning and learning dispositions in respect of climate change and energy use (Otto *et al.*, 2019). This focus should include householders and/or citizens, as households account for around 30% of overall energy use (Sovacool & Blyth, 2015). With increasing populations, global energy demand is expected to rise further.

Against this background, this study aims to explore (a) the extent to which citizens of four European countries report being interested in learning about energy-related topics, (b) the effect of individual differences on their reported interest and (c) the specific knowledge gaps that citizens report to have in relation to energy-related topics. "Citizens" is used as a collective term throughout the paper to refer to the individuals residing in a certain country and living in a household.

The study then makes practical recommendations for a more effective climate awareness provision and calls for a more interdisciplinary approach to energy literacy research. We argue that such an approach can lead to the development of a more comprehensive energy literacy framework. This study contributes to energy literacy research by exploring a novel area: interest in learning about energy-related topics. Understanding this interest is crucial, and in the long term, this can play a pivotal role in addressing the climate emergency.

Literature review

Energy literacy versus individual differences

Studies looking into citizens' energy literacy report low levels among this group (Martins *et al.*, 2020; Sovacool & Blyth, 2015). Additionally, some studies found a substantial variation in energy literacy levels between citizens with different socio-demographic characteristics (Mills & Schleich, 2012; Niamir *et al.*, 2020; Umit *et al.*, 2019). One such factor is the individual's educational level, with higher levels associated with higher energy literacy, manifested in energy-efficient technology adoption and energy conservation practice use (Mills & Schleich, 2012; Niamir *et al.*, 2020).

Another factor is economic comfort, and in literature, a positive correlation between income and energy literacy, particularly in the probability of citizens investing in energy-efficient technologies is reported (Van den Broek, 2019). Niamir *et al.* (2020) found that lower-income groups were more likely to switch to conventional providers and purchase appliances based on price rather than on energy efficiency. However, a 2019 study across 22 countries found that as citizens' income increased, they consumed more energy and reported engaging less in curtailing their energy consumption (Umit *et al.*, 2019). Less is known about the relationship between homeownership status and energy literacy. The few studies on the topic conclude that

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homeowners tend to make larger investments in energy conservation measures than tenants (Niamir *et al.*, 2020).

Two other socio-demographic factors receiving mixed results in previous research are citizens' age and gender and the relationship between these factors and energy literacy. Most studies controlling for age mainly investigated the relationship between the household uptake of energy efficiency measures and the age of the household head. Research suggests older household heads may be less likely to adopt energyefficient technologies because the expected return rate is lower than for households with younger heads, while younger households may be more likely to move and hence be less inclined to invest in energy efficiency improvements (Mills & Schleich, 2012). Combining these perspectives, Mills and Schleich (2012) hypothesised that middle-aged households should be most likely to adopt capital-intensive energy efficiency measures. Other studies observed a negative correlation between age and environmental preferences (Torgler *et al.*, 2008) or found no significant increase or decrease in energy literacy levels with age (Sovacool & Blyth, 2015).

Similarly contradictory evidence exists for the effects of gender. Some studies revealed that women have more negative attitudes towards energy (Martins *et al.*, 2020) and lower knowledge levels about energy than men (Martins, Madaleno & Dias 2021), while others conclude that women have higher energy literacy than men (Räty & Carlsson-Kanyama, 2010) and pursue more energy conservation (Niamir *et al.*, 2020).

Finally, there are studies examining the relationship between other individual differences, such as environmental attitudes and energy literacy. There seems to be a positive correlation between environmental attitudes and knowledge of the environment and environmental behavioural intentions (Janmaimool & Khajohnmanee, 2019). Martins *et al.* (2020) concluded that promotion of positive environmental attitudes in childhood is likely to contribute significantly to establishing lifelong habits of responsible energy consumption.

The post-materialist theory (Inglehart, 1990) may explain some of the varying levels of energy literacy among the different demographics. Rooted in Maslow's hierarchy of needs, this theory posits that as societies become more affluent and individuals—better off, concerns shift from material well-being to aspirations for belonging, self-expression and quality of life, with a clean and safe environment being an important dimension of the latter.

At the same time, evidence on which type of individual differences are associated with higher energy literacy remains inconsistent. This inconsistency may arise from the fact that different studies define energy literacy differently and/or have focused on different dimensions of energy literacy, such as its cognitive and behavioural dimensions.

This study addresses several gaps in energy literacy research. First, using a substantial dataset of 3,843 individuals, it provides further evidence to previous conflicting findings on the effects of individual differences on energy literacy. Second, it tackles the scarcity of research on interest in learning about energy. Third, it addresses the dearth of qualitative research exploring specific areas within energy literacy where citizens lack knowledge. There is some quantitative evidence that citizens want more information about energy use and energy-efficient behavioural choices; however, the details remain unclear (Martins *et al.*, 2020). Qualitative research is particularly valuable for exploring such areas with limited existing knowledge, giving voice to people and their experiences.

Bridging these gaps could help inform energy policies, energy literacy awareness campaigns and adult climate education programmes in respect of how they can become more targeted in reaching out to specific demographic groups.

Interest and learning

Interest is a motivational variable referring to the psychological state of engaging or the predisposition to re-engage with certain objects, events or ideas over time (Hidi & Renninger, 2006). In the literature on interest, there is a distinction between situational interest and individual

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interest. According to Hidi and Renninger (2006), situational interest is a short-lived focused attention and emotional response triggered in the moment by environmental stimuli. In contrast, individual interest is a person's habitual interest and an enduring inclination to consistently engage with specific content over time. It has been suggested that situational interest can grow into individual interest (Hidi & Renninger, 2006).

Both interest types have been associated with positive feelings and better educational outcomes. Boekaerts and Boscolo (2002) discusses that interest significantly influences learners' focus, information recall, knowledge acquisition and the level of effort they invest. For example, Rotgans and Schmidt (2011) in their study with 69 university students participating in a problem-based learning session found that interest was a significant predictor of learning, explaining about 20% of the variance in knowledge acquisition.

The evidence above shows the importance of including interest as a variable for learning and/or literacy frameworks, since it can predict the extent to which an individual sustains attention and focuses on a topic for extended periods of time, values the acquired knowledge and approaches a given topic with an exploratory mindset. This is particularly crucial for complex topics such as sustainable living, domestic energy consumption and use.

Yet, to the best of our knowledge, the only study to date that has examined interest in energy-related topics is from Vassileva and Campillo (2014), who compared two groups of low-income households in Sweden in terms of their awareness of and interests in energy-related topics and energy consumption behaviours. The authors concluded that participants from the slightly younger group (55.2-year-old compared to 63-year-old participants in the older group) and who had more members living in the household were less interested in energy-related topics. Nevertheless, the study did not report the overall interest level across the sample and did not engage with a wide range of demographics. It also lacked a qualitative exploration of what specific energy-related topics citizens were interested in.

To address the gaps discussed above, this mixed-methods study was guided by two **research questions (RQs):**

1. To what extent are adult citizens of four European countries interested in learning about energy-related topics?
   1a) What individual differences have a statistically significant effect on this interest?
2. What knowledge gaps do European citizens have about energy-related topics?

Methodology

The study was conducted as part of the Every1 project, funded by Horizon Europe/UK Research and Innovation (2022–2026) and managed by an international consortium of researchers and public authorities. The project aims to engage with European citizens to understand their preferences regarding energy use, enable them to participate in energy digitalisation and—in the longer term—to address the climate emergency. Ethical clearance for the study was obtained from the partner university leading the related work package.

Participants

The survey was administered to adult citizens in Germany, Poland, Portugal and Sweden. A total of 4,000 participants (1,000 per country) completed the survey. These countries were selected on the basis that their citizens reported largely similar levels of concern about the climate change (Eurobarometer, 2020). Additionally, these countries have very different economy sizes per capita (Eurostat, 2022a) and climate zones, which may have a different impact on citizens' interest in learning about energy. Demographics of the participants included in this study are presented in Tables 1–3 below.

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Table 1. Demographics of the whole dataset for gender, income levels, the living situation and the number of children in the household

	Gender		Income levels		Living situation	
Demographic category	Female	Male	Low income	High income	Lives in a rented property	Lives in their own property
Percentage in the sample	50.8%	49.2%	62%	38%	35.9%	64.1%
	Number of children in the household					
Demographic category	No children	1 child	2 children	3 children	4 children	5 or more
Percentage in the sample	64.8%	21%	11%	2.7%	0.2%	0.2%

Table 2. Demographics of the whole dataset for educational levels and age

	Educational level						
Demographic category	Basic/ primary	Secondary (no permission to go to HE)	Further (permission to go to HE)	Technical/ vocational	Bachelor's	Master's	Doctoral
Percentage in the sample	3.1%	17.9%	17.6%	20.3%	21.5%	18.1%	1.5%
	Age						
Demographic category	18–19	20–29	30–39	40–49	50–59	60–69	70+
Percentage in the sample	2.2%	13.7%	16.5%	16.9%	17.3%	20.1%	13.3%

Table 3. Demographics of the whole dataset for the size of the household

Size of the household (persons per household)					
Demographic category	1 person	2 people	3 people	4 people	5 people or more
Percentage in the sample	16.7%	38.8%	21.9%	16.2%	6.5%

Survey design and procedure

The survey was designed collaboratively in English by the project consortium. The questions were guided by the U.S. Department of Energy's (2017) literacy framework and were refined over multiple iterations, following regular debrief sessions between the partners and Statista survey experts (Statista, 2023), subcontracted to host and distribute the survey. The initial survey draft was translated into the official languages of the targeted countries to yield better data accuracy and was sent to 50 pilot respondents, whose feedback was considered to refine the survey.

The final survey (see supplementary material) comprised 37 questions broadly covering four areas: (1) demographics, (2) attitudes and behaviour towards climate change, (3) attitudes and behaviour towards the use of digital technologies to manage energy consumption and (4) knowledge of and attitudes and behaviour towards learning about energy-related topics. The survey featured both closed and open-ended questions.

The survey was distributed in the target countries in March 2023 via Statista. Completing the survey took approximately 10 minutes. Respondents were recruited based on national

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representative socio-demographic quotas in the targeted countries. To calculate the quotas, Statista utilised a proprietary tool, updated annually, that integrates data from Eurostat, the World Bank and Statista's own collected demographic data.

Analysis

As this study specifically aimed to explore interest and learning about energy-related topics, it focused on the fourth category of the survey described above. For our first research question (RQ1) and its sub-question (RQ1a), concerned with the levels of interest in learning about energy and individual differences, the demographic questions (Q1–Q2, Q4, Q6–Q8, Q34) and Q26 (interest in learning about energy-related topics) were analysed. We also analysed Q10 (concerns about global climate change) for RQ1, being cognisant from our literature review that environmental attitudes are often found to relate to energy literacy (Janmaimool & Khajohnmanee, 2019; Martins *et al.*, 2020). For our second research question (RQ2), concerned with knowledge gaps regarding energy, we analysed responses to the open-ended item Q33 (see supplementary material).

To address RQ1 and RQ1a, descriptive statistics and cross-tabulation-based approaches were used to analyse data in SPSS27 (Yan *et al.*, 2021). After removing responses for the demographic categories that had a very small response rate (e.g. only 0.1% of the sample reported to have no formal education), we had 3,843 responses that we used for the analyses.

To scrutinise whether the differences regarding interest in learning about energy-related topics among the respondents with different socio-demographics were statistically significant, we performed Chi-square tests and calculated the Cramer's V to assess the strengths of the association after cross-tabulation had determined significance, followed by post hoc analyses. To facilitate the analysis of the association between socio-economic status and the dependent variable, two variables were transformed into binary variables. The responses to Q34 (*What is your current living situation?*) were grouped into *owns property'*and *rents property*. The responses to Q8 *(How high is the monthly income of your household?*) were grouped into *high income* and *low income* based on the average reported monthly salary in each of the four countries (Eurostat, 2022b).

To address RQ2, responses to Q33 (*Which energy-related topics would you be particularly interested in learning more about?*) were initially translated into English from the four target languages. As Q33 was only answered by the respondents who selected *quite interested* or *highly interested* to Q26 *(To what extent are you interested in learning about energy-related topics?*), there were 3,274 responses in total. These responses (13,300 words) were then analysed inductively in NVivo 11, using thematic analysis (Braun & Clarke, 2006). We ensured the thoroughness and inclusiveness of our coding process by making it iterative and reflexive. We used peer debriefing, whereby we shared the coding table with theme labels, their descriptions and examples of participant quotes, in project consortium meetings. We then incorporated feedback and clarifications from consortium members to refine our themes.

As part of RQ2, we identified 60 codes, which were divided into five themes (hereafter "knowledge gaps") that the respondents frequently referred to as the areas where they lacked knowledge and wanted to learn more about (Table 4). For additional illustrative quotes, please refer to Appendix 1 in supplementary materials.

Results

The level of interest in learning about energy-related topics (RQ1)

The respondents reported being interested in learning about energy-related topics: 67% reported moderate interest (*I am quite interested in energy-related topics*), while a further 24.4% said that they were highly interested; 8.6% of the respondents indicated no interest. However, the

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Table 4. Coding scheme with descriptions of themes (knowledge gaps) in relation to energy-related topics

Theme	Description *Statements that concerned respondents' perceived need to*:
Energy saving in the current cost of living crisis	Respond to the current cost of living and energy crises in Europe regarding their energy consumption.
Solar energy solutions	Learn more about solar energy solutions, energy storage strategies and "dunkelflaute" (lulls in energy generation).
Making a positive difference in the current climate emergency	Learn more about what they can do to contribute to the mitigation of the climate emergency.
Energy communities	Learn more about community cooperation to use energy efficiently and address the climate crisis.
Other alternative solutions to the climate crisis	Obtain a better overview of the available alternative solutions to the climate crisis (e.g. use of hydrogen, wind energy) and solutions for storing energy.

subsequent analyses below showed that these levels of interest were not universal for the different socio-demographic groups.

The effect of individual differences on citizens' interest in learning about energy (RQ1a)

Among the variables tested, two socio-demographic variables did not yield significant differences in responses regarding interest in learning about energy—the size of the household (Q6) and the number of children in the household (Q7). The analysis of the former revealed that people living in larger households tended to be more interested in learning about energy. However, this difference was negligible, $x^2(18, N = 3843) = 77{,}439$, $p < 0.001$, Cramer's V was 0.061 ($df = 2$). The latter variable, the number of children in the household, did not yield significant differences, $x^2(10, N = 3843) = 8{,}411$, $p = 0.589$.

Below we describe the variables that revealed a statistically significant effect on the levels of interest in learning about energy-related topics.

Age

The Chi-square test showed a significant association between age and respondents' interest in learning about energy, $x^2(12, N = 3843) = 71{,}708$, $p < 0.001$. The Cramer's V was 0.097 ($df = 2$), which indicated a small effect according to Cohen's (1988) guidelines. As shown in Figure 1, the youngest respondents appeared to be the least interested in learning about energy-related topics (23.3% selected *not at all interested* among the 18–19 age group, compared with 5.9% among the 60–69 age group), and the older respondents appeared to be most interested (27.6% selected *highly interested* among the 60–69 group, compared with 14% among the 18–19 age group). The 20–29 age group appeared more likely to report moderate interest in learning about energy (73.1%) than the other age groups.

However, a pairwise z-test post hoc analysis with Bonferroni (Garcia-Perez & Nunez-Anton, 2003) revealed that there was a significant difference, adjusted $p < 0.002$, only between the 20–29 age group, who were "highly" and "quite" interested in learning about energy, and the 18–19 age group, who stated they were "not at all interested."

Gender

The Chi-square test also showed a significant association between gender and respondents' interest in learning about energy-related topics, $x^2(2, N = 3843) = 67{,}949$, $p < 0.001$. The Cramer's V was

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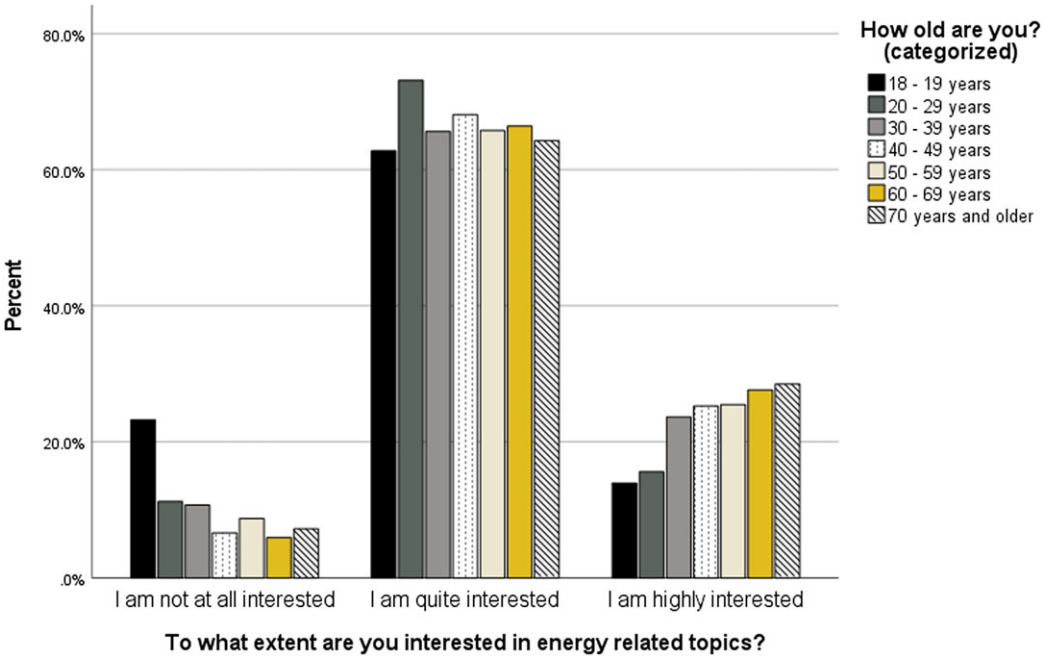

Figure 1. Interest in learning about energy-related topics by age group.

0.13 ($df = 2$), which also indicated a small effect (Cohen, 1988). We observed that respondents who self-identified as male were more likely to be interested in learning about energy than those self-identifying as women (Figure 2).

A pairwise z-test post hoc analysis with Bonferroni correction (Garcia-Perez & Nunez-Anton, 2003) revealed that there was a significant difference, adjusted $p < 0.008$, for all three types of responses (*not at all interested, quite interested* and *highly interested*) between people identifying as men and as women.

Educational level

The Chi-square test revealed a significant association between educational level and respondents' interest in learning about energy, $x^2(12, N = 3843) = 104{,}423$, $p < 0.001$. The Cramer's V was 0.11 ($df = 2$), which indicated a small effect (Cohen, 1988). Respondents with more years of educational training tended to report higher levels of interest in energy (Figure 3). For example, respondents with doctoral degrees were more likely to select *highly interested* (42.1%) than were respondents with basic education (9.9%).

A pairwise z-test post hoc analysis with Bonferroni correction (Garcia-Perez & Nunez-Anton, 2003) revealed that there was a significant difference, adjusted $p < 0.002$, between the respondents with master's degrees and doctoral degrees, who selected the responses *highly interested* and *not at all interested,* and the respondents with basic education and secondary education, who selected the same responses.

Income level and the living situation

The Chi-square test showed significant associations between respondents' income level: $x^2(2, N = 3843) = 29{,}954$, $p < 0.001$, their living situation—whether they were tenants or owners: $x^2(2, N = 3843) = 95{,}354$, $p < 0.001$, and their interest level in learning about energy-related topics.

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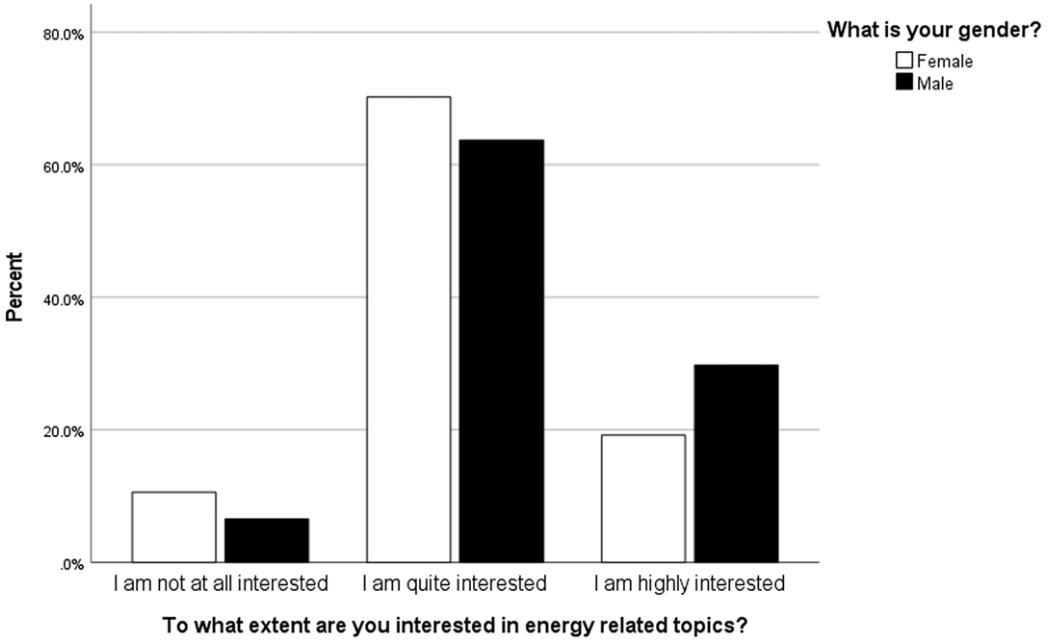

Figure 2. Interest in learning about energy-related topics by self-identified gender.

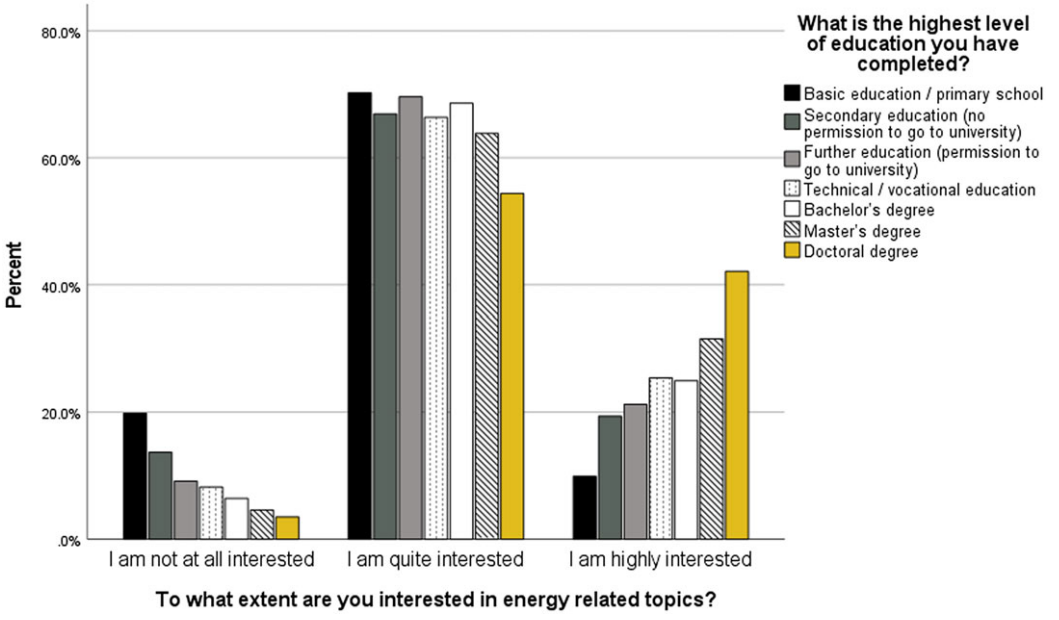

Figure 3. Interest in learning about energy-related topics by educational level.

At the same time, the Cramer's V indicated a negligible effect for the income level (0.088, $df = 1$) and a small effect for the living situation (0.158, $df = 1$) (Cohen, 1988). The three-way Chi-square test indicated a significant association between respondents' living situation and their interest in learning about energy while controlling for their reported income levels: the low-income group

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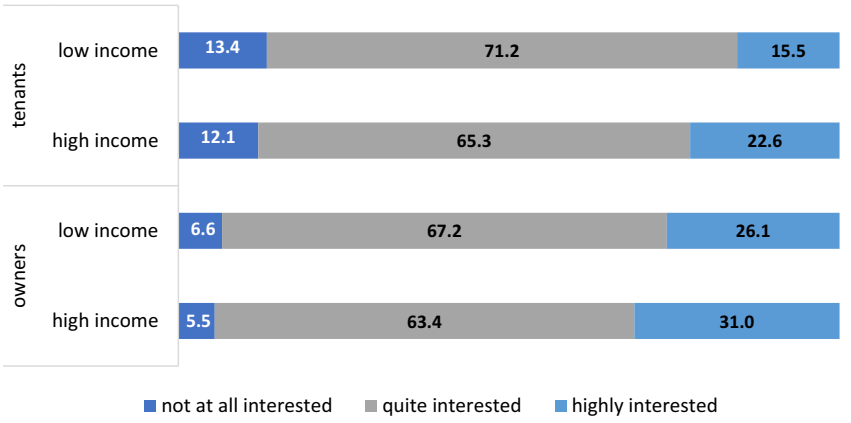

Figure 4. Interest in learning about energy-related topics by income level and living situation.
Note: The counts in the figure above are in percentages. The top two bars represent people living in rented accommodation ("tenants"), and the bottom two bars represent homeowners.

$x^2(2, N = 3843) = 59{,}778$, $p < 0.001$, the Cramer's V was 0.158 ($df = 2$) and the high-income group $x^2(2, N = 3843) = 23{,}245$, $p < 0.001$, the Cramer's V was 0.126 ($df = 2$), indicating a small effect.

It was also observed that property owners with a higher income were more likely to have a greater interest in learning about energy than respondents living in a rented property with a lower income (Figure 4).

A pairwise z-test post hoc analysis with Bonferroni correction (Garcia-Perez & Nunez-Anton, 2003) revealed that there was a significant difference, adjusted $p < 0.004$, between the tenants and house owners with high and low income, who were highly interested in energy and the respondents belonging to the same groups, who were not at all interested.

Attitudes towards climate change

A significant association was also found between respondents' attitudes about climate change and their interest in learning about energy-related topics:

- *I am concerned about global climate change*, $x^2(8, N = 3843) = 317{,}502$, $p < 0.001$, Cramer's V equalling to 0.203 ($df = 2$);
- *I am concerned about the impact of energy production and consumption on climate change*, $x^2(8, N = 3843) = 429{,}752$, $p < 0.001$, Cramer's V equalling to 0.236 ($df = 2$);
- *I believe that the way my household uses energy has an impact on the climate crisis*, $x^2(8, N = 3843) = 274{,}867$, $p < 0.001$, Cramer's V equalling to 0.189 ($df = 2$).

Thus, the strongest association between attitudes about climate change and interest in learning about energy was found to be with respondents' level of concern about the impact of energy production and consumption on climate change (with a medium effect), followed by their level of concern about climate change (with a small-to-medium effect) (Cohen, 1988).

As illustrated in Figure 5, we observed a positive association: the more concern respondents reported about climate change and the impact of energy production and consumption, the more interested they were in learning about energy-related topics.

A pairwise z-test post hoc analysis with Bonferroni correction (Garcia-Perez & Nunez-Anton, 2003) for the above question, *I am concerned about the impact of energy production and*

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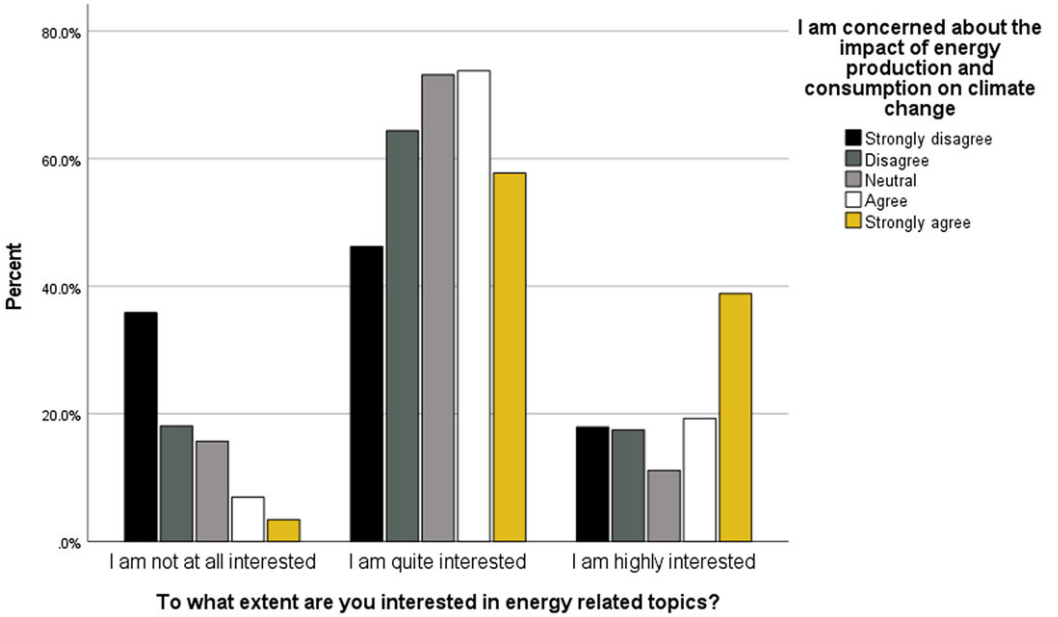

Figure 5. Interest in learning about energy-related topics by attitudes towards climate change.

consumption on climate change, revealed that there was a statistically significant difference, adjusted $p < 0.003$, between most responses, with the exception of those who selected *strongly disagree* and *disagree* in the above figure in the *highly interested in learning about energy* group and those who selected *disagree* in the *quite interested* group.

European citizens' knowledge gaps about energy-related topics (RQ2)

Energy saving in the current cost of living crisis

The analysis of survey's open-ended question showed the sharp increase in energy prices in early 2022 and the consecutive cost of living crisis as a frequent point of reference among all respondents, across all socio-demographic categories. They seemed to have provided a new lens for the climate emergency in that all respondents wanted to learn how to use less energy and to reduce energy costs. The two responses below illustrate this point:

> *What can help me save energy at home and is good for the environment?* (P_922, 67-year-old male, Germany)

> *I want to learn more about cost reduction and the environmental impact of the energy solutions I am using.* (P_647, 42-year-old male, Portugal)

Besides inquiries about reducing energy costs, respondents frequently voiced the need to learn about becoming more self-sufficient in producing energy at home. They expressed their desire to learn about individual opportunities to self-supply electricity, independence from energy companies, ways to use their own energy sources as a tenant and sustainability. Some responses mentioned the need to know how to become more independent both at an individual and a national level. For example:

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> *I want to learn about more accessible gas supply and exploration in our country, instead of receiving them from abroad; domestic microgeneration.* (P_919, 24-year-old female, Portugal)

Another prominent subtheme within energy saving was the need to learn more about personal energy consumption management: specific measures and digital technologies that can help individuals determine their energy consumption and improve energy efficiency. Respondents repeatedly mentioned their lack of knowledge about optimising their consumption, smart home monitoring and technologies to help them control and use energy more intelligently:

> *A service like the one that Aftonbladet [Swedish newspaper] has with examples of what the use of household appliances costs daily based on the electricity price . . . e.g., showering for 15 minutes costs SEK 15.* (P_898, 46-year-old male, Sweden)

Solar energy solutions

Photovoltaics and solar energy solutions were the most frequently cited energy solutions that respondents appeared eager to learn more about. Respondents across the sample discussed affordability, efficiency, connectivity and self-sufficiency regarding solar energy solutions as specific areas about which they lacked knowledge:

> *I would like to know more in depth how to use solar energy in homes or buildings in order to optimise conventional energy.* (P_3120, 19-year-old female, Portugal)

Respondents from Germany further flagged a lack of knowledge about photovoltaic solutions for smaller properties such as flats. They sought more information about solar systems for balconies, their pros and cons and their installation cost versus profit.

Finally, many reported a need for more information about the ways and opportunities to store solar energy and safeguard the grid when the sun is low:

> *What happens in "dunkelflaute" [lulls in energy generation in which little or no energy can be generated, because there is no sunlight]? Do we then buy 'dirty' energy from abroad?"* (P_1389, 70-year-old male, Germany)

Making a positive difference in the current climate emergency

Another theme in respondents' comments was a lack of knowledge about how to make a positive difference in the current climate emergency and what actions one can take on a personal level to contribute to its mitigation. Respondents particularly stressed practical considerations—what can be done in everyday life "to help the climate." For example:

> *How can we use energy more responsibly and efficiently to minimise economic and environmental costs? In practice, what can families do?* (P_1578, 35-year-old female, Portugal)

Some respondents also sought for examples of good practices regarding energy consumption and sustainable living, both on an individual level and internationally:

> *I would want to know which countries are the most effective in terms of making a minimal contribution to the climate crisis – what they learn from and how.* (P_125, 69-year-old female, Sweden)

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I am interested in the information that details where my energy comes from and how it is produced in addition to its impact on the planet. (P_1516, 18-year-old male, Portugal)

As with other themes, respondents living in smaller properties further wondered about the available energy solution choices to them and the differences they could make regarding climate crisis mitigation.

Energy communities

Respondents frequently indicated their need to learn more about community cooperation for a more efficient use of energy and for sustainable living. They sought information about creating an energy neighbourhood and setting up shared solar panels and/or shared solar parks. Some respondents commented about feeling disconnected from energy production. The energy delivery infrastructure to people's homes remains mostly unseen, and within people's homes, this delivery infrastructure is hidden beneath floors and walls emerging only at convenient access points. Respondents further commented that the source of energy delivered to their homes is often undifferentiated, and their understanding of energy is limited to the cost to individuals. They also raised the need to gain a better understanding of the energy production cycle, through community cooperation:

I want to learn how to create an energy neighbourhood, and more generally, how to become more involved in how the entire energy ecosystem works. (P_952, 34-year-old male, Sweden)

I would want to know about the source of energy that is supplied to my house – where it comes from, and whether it is renewable or not. (P_708, 35-year-old female, Poland)

Other alternative solutions to the climate crisis

Although solar energy was the most frequently cited energy solution across the sample, respondents also mentioned several other alternative energy solutions they wanted to learn more about. These included a better understanding of renewable and/or green energy sources, ways power companies handle the demand for renewable power and the possibility of combining these sources for a more efficient energy production:

What plans are there to secure the energy supply in the future, e.g., expansion of the electricity grid, new types of energy, etc? (P_914, female, 29 years old, Sweden)

In terms of specific alternative energy solutions, respondents flagged their lack of knowledge about hydrogen use in cars, heat pumps as an additional source of heating and wind power and turbines—for the latter, whether it was possible to install one in the back garden of the house. Finally, respondents raised questions about the possibilities for storing energy (e.g. storing heat energy in buildings or geothermal heating).

Discussion

In the face of a rapidly intensifying global climate emergency, numerous studies warn that people's energy literacy is worryingly low (Martins *et al.*, 2020; University of Queensland, 2019). This study provides a greater understanding of the extent to which citizens are interested in learning about energy-related topics and the effect of individual differences on their interest while exploring the specific knowledge gaps they have in relation to energy-related topics.

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The findings reveal that the majority of participants are interested in learning about energy-related topics, with most respondents indicating moderate interest (RQ1). The fact that few survey participants (24.4%) selected the "highly interested" response was surprising, in the wake of the tangible energy crisis resulting from the ongoing Russian-Ukrainian conflict in 2022. Since no existing research reported the overall citizens' interest level in learning about energy, this finding is important to energy literature.

Our further finding that reported levels of interest significantly varied across different socio-demographic groups (RQ1a) might explain why the overall reported level of interest was moderate. Several variables—age, gender, educational level, level of income and living situation and attitudes towards climate change—showed a significant association with respondents' reported interest level in energy. Overall, older (particularly 60–69-year-olds), more educated (especially those with masters and doctorate degrees), male property owners with a higher income, who are already concerned about the impact of energy production and consumption on climate change, appeared to be most interested in learning about energy. The latter relationship, concern about the energy consumption impact and interest, had the highest effect size among the variables tested in this study. This is in line with previous research that showed a significant positive correlation between environmental attitudes and knowledge and environmental behavioural intentions (Janmaimool & Khajohnmanee, 2019). To some extent, the findings above can be explained by the post-materialist theory (Inglehart, 1990), which suggests that as societies become more affluent and individuals—better off, their focus shifts from material concerns to desires for belonging, self-expression and overall quality of life, including a clean and safe environment.

Our analysis revealed only small effect sizes for the age, gender, educational level variables and the three-way association between citizens' living situation, interest in learning about energy and reported income levels. While these small effect sizes may seem inconsequential on an individual level, if one multiplies the observed effect size by, for example, the number of women in Europe, it becomes clear that there might be a salient social divide in public interest and uptake on the topic. This suggests that specific demographic groups, despite showing only a slight statistical difference, could benefit significantly from tailored educational programmes or policy interventions.

Additionally, the finding about older respondents being more interested in learning about energy makes a useful contribution to the existing research, where evidence regarding the relationship between age and energy literacy is contradictory. Some studies have hypothesised that more mature, middle-aged citizens are more likely to explore and invest in energy efficiency measures as they are less likely to move house, while expecting to live long enough to see the return of their investment (Mills & Schleich, 2012); other studies have found no such relationship (Sovacool & Blyth, 2015). Our post hoc analysis further revealed a statistically significant difference only between the 20–29 age group and the 18–19-year-olds, with the youngest respondents being the least likely to be interested in learning about energy. It would be reasonable to assume that life experience and being responsible for paying energy bills is a driver for developing interest in energy topics.

Our study provided further valuable evidence about the relationship between gender, income and homeownership status. Again, existing evidence on this topic (Martins *et al.*, 2021; Niamir *et al.*, 2020; Räty & Carlsson-Kanyama, 2010; Umit *et al.*, 2019) is contradictory. Energy-efficient solutions require capital and investment, which might explain why the respondents who earn aboveaverage salaries and who have more agency and autonomy as part of their homeowner status, expressed more interest in learning about energy topics. An interesting finding was that respondents who self-identify as male were significantly more likely to select the "highly interested" response than those who self-identify as women. The wider evidence that women already do most of the world's unpaid care work and that emergencies such as the Covid-19 pandemic disproportionately increase their care burden in comparison with men (Power, 2020) might explain why women are more likely to be unwilling to take on a learning opportunity and why they express less interest in learning about energy than men.

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The thematic analysis of participants' knowledge gaps (RQ2) revealed five knowledge demand areas: (1) how to respond to the ongoing cost of living crisis regarding one's energy consumption; (2) how affordable, efficient and self-sufficient solar energy solutions are and how to store solar energy; (3) how to contribute to the mitigation of the climate emergency on a personal level; (4) how to cooperate with others to use energy efficiently; and (5) what other alternative solutions exist regarding mitigating the climate crisis. Several of these areas address the dimensions of energy literacy covered in the energy literacy definition adopted in this study (U.S. Department of Energy, 2017).

It was notable that solar energy emerged as the most sought-after topic among renewable energy solutions. This could be because, in contrast to wind, hydro, geothermal or biomass energy, solar energy solutions do not need to be extracted and maintained by large businesses before they can power a community, and they are becoming increasingly accessible for domestic use.

The above discussion shows how closely connected energy literacy is to the perception and understanding of economic benefits. In this study, some respondents reflected that since energy is often "invisible," with energy delivery infrastructure often hidden beneath one's house floors and walls, one's understanding of energy is mainly through cost to the individual and paying the energy bills. Strategies to use energy efficiently to lower utility bills was, in fact, the most frequently cited topic that respondents wanted to learn more about among the five identified knowledge gap areas. An explanation for this might also be the ongoing energy and cost of living crises in Europe, which have started to drive people's desire to learn how to take control of their own energy usage.

Finally, another interesting finding was the keen interest expressed by some respondents in learning about community cooperation. Respondents mentioned the need to learn more about how to create an energy neighbourhood, implement collective solar panel initiatives and develop shared solar parks in their local area. This finding contributes to the wider discussion and realisation that sustainable living is a shared responsibility and requires collaboration. This also suggests that although energy provision is generally top-down (Snow *et al.*, 2022), citizens do want to participate in the process.

Limitations

Although this study allowed us to address a number of gaps in energy literacy research, a number of limitations should be mentioned. First, due to the constraints of a single study and its specific focus on citizens' interest in just four countries, the analysis was limited to the survey items relevant to the RQs. Future research could explore additional variables featured in the survey (e.g. citizens' interest in learning about energy compared with their interest in digital technologies and adoption of them for more efficient energy monitoring) and/or benchmark this study's results across different geographical contexts.

Second, while the study used mixed methods to shed light on the underexplored research area, adopting an explanatory mixed-methods research design could have yielded additional insights (Rets *et al.*, 2023). Specifically, one could explore the reasons behind the observed quantitative findings. Given the scarcity of qualitative research on energy literacy, future research could utilise interview and focus group methodologies to explore the factors that drive interest in learning about energy among different groups of citizens.

Implications and conclusions

Regarding theoretical implications, we suggest that energy literacy frameworks should incorporate the concept of "interest in learning about energy" into their affective dimensions. As discussed earlier, investigating interest could provide invaluable insights. In the longer term, the level of interest an individual holds towards energy topics can play a pivotal role in addressing the climate

https://doi.org/10.1017/aee.2024.37 Published online by Cambridge University Press

emergency, as the ultimate objective of energy literacy is to help individuals become more energy conscious and bring them closer to sustainable living practices.

Our study also identified the groups of citizens who are less interested in learning about energy, as well as the sought-after areas of energy-related knowledge demand among citizens. These findings hold several practical implications. The primary implication concerns climate education programmes, energy literacy awareness campaigns and energy policies that can use these insights to become more tailored in reaching out to specific demographic groups and helping them improve their energy literacy. An important step towards this can be the provision of accessible learning resources on the energy-related topics identified in this research, for example, by using free open online courses (e.g. OpenLearn, 2024), which allow learners to engage at their own pace. This is particularly beneficial for vulnerable learners, such as women and/or economically disadvantaged individuals. Integrating the topics identified in this research into school curricula can further appeal to younger audiences, as these topics call for practical materials, which are directly relevant to everyday life experiences. Finally, leveraging trusted community leaders can help disseminate this knowledge to disadvantaged groups, ensuring wider reach and impact.

The complexity within our findings indicates that there is no one-size-fits-all approach to enabling and empowering individuals across Europe to make informed energy choices. Individual interest is an important element in enhancing energy literacy and is influenced by many factors including people's awareness of the impact of climate change and financial pressures to reduce the cost of energy to households.

Most importantly, as "big" research problems cannot be solved within one discipline, these findings are a call for more interdisciplinary research on energy literacy. This would allow a greater focus on such concepts as interest in learning about energy, which in turn can improve the likelihood that individuals will place value on acquired knowledge about energy topics and choose to act upon it. Creating platforms for knowledge exchange between disciplines, involving stakeholders from various sectors and developing collaborative research projects could enhance the capacity for interdisciplinary research on the topic.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/aee.2024.37.

Acknowledgements. The views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the CINEA can be held responsible for them.

Financial support. This project is co-funded by the European Union under the EU Programme HORIZON-CL5-2021-D3-02 under the grant agreement number: 10175596.

Ethical standard. The ethical approval for this research was obtained by the project consortium partner institution, Eindhoven University of Technology (TU/e), January 23, 2033, reference number ERB2022IEIS50.

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Cite this article: 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* **0**, 1–18. https://doi.org/10.1017/aee.2024.37