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Review

Know Better, Power Smarter: How Energy Literacy Relates to Household Energy Use

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ABSTRACT

Reaching the climate goals of the Paris Agreement requires major changes in how households use and manage energy. Energy literacy (EL), understood as people's knowledge of how energy works and how their actions affect consumption, can help make these changes possible. However, research on EL has mostly focused on energy saving and has rarely explored how it relates to flexibility, such as shifting electricity use to different times of the day.

This paper systematically reviews 45 peer-reviewed studies to understand how EL relates to household energy behaviour. We identify four groups of behaviours linked to EL: energy efficiency actions, energy efficiency investments, energy flexibility actions, and energy flexibility investments. Most studies find that people with higher EL are more likely to save energy and invest in efficient technologies. Evidence on flexibility is still limited but points to similar trends. We also show that specific skills matter: financial literacy and cost awareness may help with some investment decisions, while understanding tariffs and being able to adapt routines support flexibility.

The review provides a clear framework that links knowledge and skills to practical outcomes. Strengthening energy literacy could make households more efficient, flexible, and active participants in a low-carbon energy system.

Contents

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Abbreviations

DLC	Direct load control
EL	Energy literacy
ERFL	Energy-related financial literacy
RES	Renewable energy sources

1. Introduction and background

The Paris Agreement, adopted in 2015, raised awareness of the urgent need to reduce carbon emissions to combat climate change, and established ambitious public energy policy targets [1]. Achieving these targets requires significant reductions in greenhouse gas emissions, particularly through changes in energy consumption patterns [2]. First, the imperative to reduce energy consumption and increase efficiency (which became prominent during the energy crisis of the 1970s) remains highly relevant today [3]. Second, the ongoing energy transition, characterised by increasing electrification and the integration of renewable energy sources (RES), poses a range of new challenges to power system operators [4].

The paradigm of power system operations is in the process of dramatic change. While power systems in the past were led by the principle of “demand leads, generation follows”, the power systems of the future will be led by the opposite principle of “generation leads, demand follows” [5]. The main equation in power system operation is the balance of electricity generation and demand, if this balance is not maintained, the power system can face major disruption and even collapse [6].

Initially, demand was inflexible or uncontrollable, meaning that there was no way to manage demand in order to maintain this balance. But this was not a problem as there was considerable generation flexibility due to the ability to control the operation of thermal (fossil-fuelled) and hydropower plants. Later on, flexibility measures on the demand side have been introduced in some sectors and regions. For instance, industrial flexibility has been implemented in Germany for decades [7], and Sweden introduced dynamic electricity tariffs for residential consumers as early as the early 2010s [8].

Demand-side flexibility in the residential sector remains limited in most countries, as households rarely have incentives to shift consumption; despite being a longstanding concept, its uptake across Europe is recent and uneven. This contrasts with the future power system, where the decarbonisation of electricity generation leads to the decommissioning of controllable thermal power plants and the integration of uncontrollable RES [4]. In such a future system, the system will lose traditional flexibility providers, which will need to be replaced. Replacement must come from the demand side of the energy balance equation, where demand can be managed to provide the required flexibility [9]. Currently, demand management is not able to provide sufficient flexibility to the power system [10].

The residential sector now represents over one-quarter of final electricity consumption in the European Union, making it the second-largest sector after industry [11]. This means that considerable flexibility potential lies in the residential sector, but only if consumers are aware, engaged, and equipped to respond. In this context, households are required to manage their energy consumption more actively [12]. However, as the energy sector continues to evolve, featuring a proliferation of related options and solutions [13], it becomes challenging for household decision-makers to navigate these choices. Substantial knowledge and understanding are required to identify optimal energy-related arrangements [12].

Energy literacy (EL) is emerging as a key enabler in efforts to transition to more sustainable energy systems [14]. It implies an understanding of the importance and function of energy in the world and in daily life, along with the ability to apply this understanding to answer questions and solve problems [15]. Energy-literate individuals are better aware of how energy is used and generated. They recognise the implications of energy-related decisions and the importance of conserving energy. Ultimately, they tend to apply this understanding by taking appropriate action and are more likely to commit themselves to the more efficient use of resources [16]. In this paper, we adopt this definition of EL.

The understanding of this concept has evolved significantly since the first study by Gaskell and Pike [17] in 1983, which linked EL to self-reported energy efficiency actions. They found that “savers” were more knowledgeable and motivated by the potential to make personal financial savings. They defined EL as knowledge of energy-saving practices, coupled with beliefs about personal finance, health, and energy consumption. Subsequent key contributions further shaped the understanding of EL. DeWaters and Powers [16] defined it as a multidimensional construct encompassing three dimensions: the cognitive dimension (which involves understanding energy concepts, sources, and systems, and the ability to apply this knowledge to solve problems); the affective dimension (which includes attitudes, values, and personal responsibility towards energy use, fostering positive attitudes towards energy efficiency actions); and the behavioural dimension (which focuses on the practical application of energy knowledge in daily life, such as reducing consumption and using energy-efficient technologies). Later, Martins et al. [14] emphasised the importance of applying energy and personal finance knowledge to real-life scenarios, and highlighted the challenges consumers face in understanding energy consumption data.

Finally, the work of Van Den Broek [18] introduced a conceptual typology to categorise the different aspects of EL. This typology is designed to provide a structured framework for understanding the various dimensions of EL. She identified four types: device EL, action EL, financial EL, and multifaceted EL. Device EL refers to knowledge about the energy consumption of household appliances. Action EL implies an understanding of energy-saving actions at home. Financial EL is the ability to assess the impact on personal finances of energy consumption and opportunities for making savings. Multifaceted EL includes a comprehensive understanding of energy concepts, which encompasses production, supply, environmental impacts, and active engagement in energy efficiency actions. This approach provides a detailed and organised way to understand and study EL. It breaks down this broad concept into manageable and specific types, facilitating a more focused approach to research and the development of targeted policy measures.

While the existing literature contains many significant contributions, we have identified several gaps and challenges that require attention. First, none of the aforementioned papers addresses concerns about flexibility or related concepts within their frameworks. Addressing this gap is crucial as flexibility in energy systems is becoming increasingly important in the context of the energy transition [4]. Second, although several studies have investigated the relationship between EL and the energy-related behaviours of households [18], there is a lack of a comprehensive overview that brings these findings together.

A comprehensive synthesis of these studies is essential to develop an understanding of how EL influences household energy behaviours, which can inform more effective policy and educational interventions. Third, different studies use diverse definitions and measurements of EL, with each including different knowledge and skills. Understanding these varied definitions and measurements is important to grasp the full scope of EL and to identify the most effective ways to enhance it when needed.

To address these gaps, we carry out a systematic literature review that answers the following research questions:

- Which energy-related behaviours have been studied in terms of their relationship with EL? And in particular, are there any flexibility-related studies among them?
- How is EL associated with energy-related behaviours?
- What are the skills that effectively shape these behaviours?

Based on our review, we propose a framework linking EL to four categories of energy-related behaviours, each associated with specific knowledge and skills. These include actions and investments related to energy efficiency, as well as actions and investments aimed at increasing flexibility. Efficiency-related behaviours require basic energy knowledge and, in the case of investments, financial skills. Flexibility actions require an understanding of time-dependent energy use, with flexibility investments also demanding financial literacy.

With this article, we contribute to the discourse on how to actively include residential consumers in the energy transition. While previous reviews have rather focused on dimensions or types of EL [14,16,18], we propose a framework to explain and map how EL is related to energy use. This novel approach offers aggregated insights into how different skills are related to energy behaviours. Additionally, our results suggest that increasing the EL of households can be associated with behavioural changes that lead to higher levels of energy efficiency and flexibility. Compared to other personal characteristics, EL can be increased through targeted policies and programmes, making it a valuable tool for researchers and policymakers. Our review also identifies a gap in the existing literature. Despite the growing importance of the need for flexibility in managing household electricity demand, this has not been sufficiently explored in EL research. By focusing on these areas, our work not only advances academic understanding but also provides practical insights that can help shape effective energy policies and programmes, ultimately promoting more sustainable and efficient energy use.

This paper is structured as follows. Section 2 describes the methodology used for the structured literature review. The results are divided into three parts: Section 3.1 presents our proposed classification framework of energy-related behaviours associated with EL. Sections 3.2 to 3.5 present the findings of the literature review, organised by the different behaviours associated with EL. Section 3.6 explains the methodological approaches used by the analysed papers, and Section 3.7 elaborates on what skills are relevant for EL across different groups. Section 4 analyses the main findings, highlighting the research gaps and issues that emerged from our review, and discusses the limitations of the study. Finally, Section 5 draws conclusions and presents prospects for future research.

2. Methodology

2.1. Definition of energy literacy

The concept of EL adopted in this study builds on and extends existing frameworks developed by DeWaters and Powers [16] and Van Den Broek [18]. DeWaters and Powers [16] conceive EL as a multidimensional construct that includes cognitive, affective, and behavioural elements, underlining the link between knowledge, understanding, and behavioural capacity. Van Den Broek [18] complements this view by underlining the behavioural aspect, describing EL as the ability to make informed decisions about energy use and to act accordingly.

This review is situated within that multidimensional perspective. EL is understood here as the capacity to engage with and interpret information about one's energy consumption, combining awareness, practical knowledge, and decision-making ability. While this interpretation remains close to the earlier frameworks, it also reflects more recent applications that emphasise how EL enables action across a range of household decisions.

In addition to EL, some of the reviewed studies address the concept of energy-related financial literacy (ERFL). It is the combination of energy-specific knowledge and financial understanding that enables individuals to make informed decisions about energy-related investments [19]. While EL focuses on understanding energy systems and consumption patterns, ERFL adds a financial dimension that captures individuals' ability to evaluate tariffs, compare long-term costs and savings, and assess the financial implications of adopting new technologies. The review discusses these dimensions separately to reflect their potentially distinct roles in shaping household energy decisions.

Finally, for each paper, we evaluated which skills were included in its definition of EL. This was done by analysing the authors' definitions, the methods sections, and, where available, the questionnaires. The results are presented in Section 3.7. We define skills as specific cognitive, analytical, or behavioural competencies that enable individuals to perform energy-related tasks effectively, from recognising and interpreting relevant information to making informed decisions and adapting behaviours. These skills encompass both domain-specific knowledge (e.g. understanding energy concepts, tariffs, or renewable technologies) and cross-cutting abilities (e.g. cost awareness, data interpretation, attention management, behavioural adaptation) that support different types of energy outcomes, such as efficiency actions, efficiency investments, flexibility actions, and flexibility investments.

2.2. Research design and approach: A systematic review

To assess the relationship between EL and household energy-related behaviours, we conducted a systematic literature review in accordance with the PRISMA methodology [20], with a special focus on social sciences following Petticrew and Roberts [21]'s guidelines. We focused on studies that quantitatively or qualitatively assessed the relationship between EL and energy behaviours at the household level.

During the identification phase, we searched the Scopus database using the search string depicted in Fig. 1. The search string was enhanced from an earlier, shorter, and less refined version of this article (citation excluded to avoid mentioning author information), following feedback from other researchers at the (conference excluded to avoid mentioning author information). The search was last updated in July 2025. Reference lists of relevant articles were also screened to identify additional sources.

During the screening phase, we imported all search results into a reference manager. We removed duplicates, and screened titles and abstracts to assess relevance. We excluded studies if they were not peer-reviewed or did not focus on households.

During the eligibility assessment, full-text versions of the remaining articles were retrieved and evaluated against the following criteria:

1. The study addressed EL (conceptually or through measurement);
2. The study refers (not exclusively) to the relationship between EL and energy-related behaviours (concrete actions taken by households to reduce, shift, or optimise their energy use).

We found 45 studies that met the eligibility criteria and we included them in the review. These studies span diverse geographical settings and employ varied methodologies, ranging from cross-sectional surveys to field experiments and qualitative interviews. Each was analysed according to its methodological design, definition of EL, behavioural

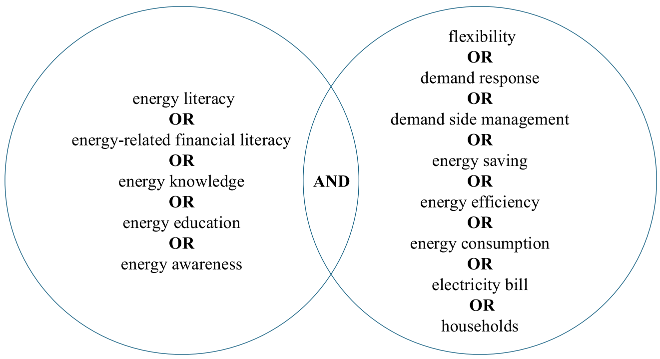

Fig. 1. Keywords and Boolean operators used for the systematic review using the TITLE-ABS-KEY filter.

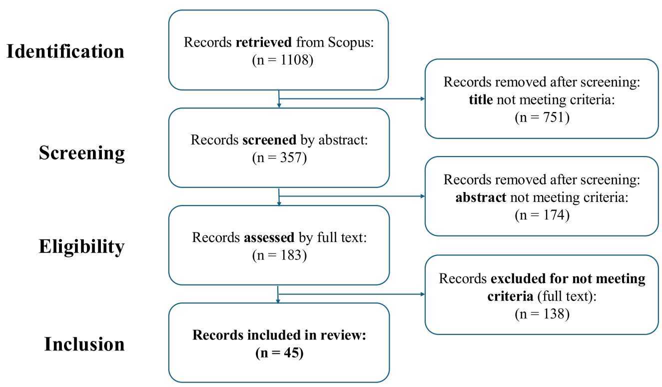

Fig. 2. Record selection procedure based on PRISMA workflow.

focus, and reported effect. Fig. 2 illustrates the different stages of the PRISMA process and shows how many records were excluded at each step, from initial identification to the final set of included studies.

Finally, we analysed the selected literature to inductively identify four main groups of household energy behaviours that are linked to EL: energy efficiency actions, energy efficiency investments, energy flexibility actions, and energy flexibility investments. These categories are discussed in detail in the following sections. Our approach follows the example of Van Den Broek [18], meaning that the classification emerged from patterns observed in the existing body of research rather than from a pre-defined theoretical framework. By deriving the categories directly from the literature, this method captures the diversity of how EL has been conceptualised and operationalised across studies. It also provides a more concrete and nuanced understanding of how EL has been investigated in relation to different types of energy-related behaviours across a range of disciplinary perspectives.

3. Results

This section presents the main findings of our review. The selected studies were examined with reference to how EL, as well as ERFL in some cases, relates to household energy behaviour. It begins with the introduction of the conceptual classification framework that we designed to link EL to household energy behaviour in Section 3.1. The classification is grounded in existing frameworks but is adapted to reflect the empirical focus and inductive categorisation developed in this study. The following four sub-sections examine each behavioural group in turn: energy efficiency actions, energy efficiency investments, energy flexibility actions, and energy flexibility investments. Each sub-section discusses how EL is conceptualised in the selected studies, how it relates to the specific behaviour in question, and whether ERFL also plays a role. We then focus on the methodological approaches of the included papers, describing research paradigms, study designs, and the skills in EL.

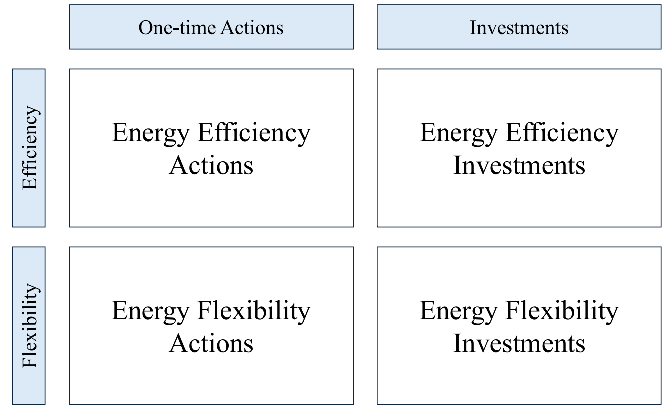

Fig. 3. Classification Framework of energy-related behaviours linked to energy literacy.

3.1. *Energy literacy and behaviour classification framework*

In this section, we present the classification framework we developed from the literature review to map the energy-related behaviours which are linked to EL. The classification is shown in Fig. 3.

First, we classify behaviours according to their primary purpose, which can be either energy efficiency or energy flexibility [22]. Energy efficiency encompasses household actions that seek to lower total energy consumption, either through reduced usage or improved performance of appliances and systems. The latter refers to behaviours that aim to provide demand-side flexibility to the power system [23]. However, while energy efficiency actions and investments have been researched for several decades [24], the need for demand-side flexibility has emerged only recently, in conjunction with the energy transition becoming a higher priority [5]. Consequently, behavioural changes related to flexibility have been less studied compared to energy savings. This is reflected in our literature review, which includes more papers related to efficiency (35) than flexibility (10).

Second, we distinguish behaviours by the type of change involved, which can be either actions that alter consumption patterns or investments in technologies that enhance efficiency or flexibility. The former refers to one-time actions undertaken to reduce energy use or to shift consumption to different times of the day or week. While effective, these actions require consumers to develop new habits, stay informed about electricity prices, or even sacrifice some comfort [25]. On the other hand, investing in energy efficiency or flexibility technologies involves purchasing and adopting advanced systems that lower energy consumption or enhance the adaptability of energy supply and demand. Although they involve a financial cost, these technologies require minimal or no effort from consumers, as they provide the same services with reduced power demand or automate the shifting of consumption. Investments in these technologies not only alleviate the burden on consumers but may also lead to long-term environmental and financial benefits for them [26].

Taking these two distinctions into account, we identify four main groups of energy-related behaviours. The groups are defined as follows:

- Energy Efficiency Actions: deliberate attempts to reduce energy use. This includes adopting practices and making behavioural changes aimed at reducing consumption, while still meeting desired needs and maintaining comfort levels [27]. Examples of these actions include turning off lights when not in use, unplugging electronic devices, and avoiding stand-by mode.

Table 1
Summary of included studies.

Groups	Source	Year	Country of study	Relation with EL	Research method
Efficiency actions	Dominitz et al. [31]	2023	Israel	Positive	Mixed
	Hoody et al. [32]	2021	USA	No	Qualitative
	Dalvi et al. [33]	2016	India	Positive	
	Kvist Svangren et al. [34]	2020	Denmark	Positive	
	Langevin et al. [35]	2013	US	Positive	
	Ali et al. [36]	2019	China	No	Quantitative
	Brounen et al. [37]	2013	Netherlands	No	
	Zhang et al. [38]	2021	China	No	
	Appiah et al. [39]	2023	Ghana	Positive	
	Broberg and Kažukauskas [40]	2021	Sweden	Positive	
	Gaskell and Pike [17]	1983	UK	Positive	
	Kalmi et al. [41]	2021	Finland	Positive	
	Kantenbacher and Attari [42]	2021	USA	Positive	
	Mogles et al. [43]	2018	UK	Positive	
	Mogles et al. [44]	2017	UK	Positive	
	Sayarkhalaj and Khesal [45]	2022	Iran	Positive	
	Schwartz et al. [46]	2013	Germany	Positive	
	Trotta [47]	2021	Finland	Positive	
	Valenzuela-Flores et al. [48]	2023	Chile	Positive	
Efficiency investments	Bera et al. [49]	2025	India	Positive	Mixed
	He et al. [50]	2022	China, Netherlands	No	Quantitative
	Dharshing and Hille [51]	2017	Switzerland	No	
	Ropuszyńska-Surma and Węglarz [52]	2018	Poland	No	
	Asmare et al. [53]	2023	Lithuania	Positive	
	Baikowski [54]	2018	Germany	Positive	
	Blasch et al. [55]	2022	Switzerland	Positive	
	Blasch et al. [56]	2019	Switzerland	Positive	
	Blasch et al. [19]	2021	Italy, Switzerland, Netherlands	Positive	
	Boogen et al. [57]	2021	Italy, Switzerland, Netherlands	Positive	
	Buchtele et al. [58]	2023	Czech Republic	Positive	
	Damigos et al. [26]	2021	Greece	Positive	
	Ebrahimigharehbaghi et al. [59]	2022	Netherlands	Positive	
	He et al. [60]	2022	Netherlands	Positive	
	Olsthoorn et al. [61]	2023	Germany	Positive	
	Stikvoort et al. [62]	2018	Sweden	Positive	
Flexibility actions	Nilsson and Bartusch [63]	2025	Sweden	Positive	Qualitative
	O'Sullivan and Viggers [64]	2021	New Zealand	Positive	
	Walker and Hope [65]	2020	UK	Positive	
	Dütschke and Paetz [66]	2013	Germany	Positive	Quantitative
	Li et al. [67]	2017	Netherlands	Positive	
	Reis et al. [68]	2021	Portugal	Positive	
	Ruokamo et al. [69]	2019	Finland	Positive	
Flexibility investments	Chadwick et al. [25]	2022	OECD countries	Positive	Qualitative
	Rahman et al. [70]	2025	Finland	Positive	
	Andolfi et al. [71]	2024	Luxembourg	Positive	Quantitative

- Energy Efficiency Investments: the investment in more efficient appliances, or in overall household efficiency, such as isolating the outer shell of the building or installing rooftop photovoltaic panels [19].
- Energy Flexibility Actions: these involve consumers actively monitoring electricity prices or other grid signals and manually adjusting their consumption accordingly, for example, by turning off appliances during peak hours or shifting energy-intensive activities to off-peak times [28].
- Energy Flexibility Investments: investment in technologies to manage energy consumption without the need for continuous user intervention [29]. These include smart plugs, home energy management systems, and smart chargers that can automatically adjust energy usage in response to signals from the grid or dynamic tariffs [30].

Table 1 shows the studies included in this review and specifies when and where each study was performed, which research method the authors used, the group it belongs to and whether the relation they found with EL is positive, negative, or absent.

In the following four sections, we provide a detailed description of each energy-related behaviour group. Each section states how many publications were found related to that group and whether the relation with EL is positive or negative; then it explains how EL relates to these behaviours.

3.2. Energy efficiency actions

In this section, we study how EL contributes to the implementation of energy efficiency actions in households. We found 19 publications which investigate EL as one of the determinants of implementing energy efficiency actions in households. Of these papers, 14 publications indicate a positive relationship between EL and energy efficiency actions, while 4 find no relationship between the two.

We begin by reviewing studies demonstrating how EL influences actions such as switching off standby power and adjusting thermostats. We then explore mixed findings in domains such as heating and cooling, before assessing the impact of educational interventions and feedback programs. Finally, we reflect on why awareness sometimes fails to translate into practice and discuss implications for designing more effective literacy-based initiatives.

Most studies indicate that EL is associated with a higher likelihood of taking energy efficiency actions. The first study suggesting the existence of this relationship was carried out by Gaskell and Pike [17], who found that energy savers were more knowledgeable and motivated by the potential to make personal financial savings. The following studies confirmed and expanded on this finding. Appiah et al. [39] noted a positive correlation between EL and energy-saving actions, indicating that those who understand energy better are more likely to take steps to conserve it. Langevin et al. [35] highlighted that energy knowledge and education are key enablers for adopting energy efficiency actions such as turning off equipment rather than using standby mode or adjusting the thermostat at night. Sayarkhalaj and Khesal [45] further supported this by showing a correlation between EL and energy efficiency actions. Schwartz et al. [46] found that increased EL leads to changes in consumption behaviour. Furthermore, Mogles et al. [43] found that EL is a valuable and sensitive input for agent-based modelling of energy behaviour change. Trotta [47] found that electricity awareness is correlated with sensible financial choices and lower electricity consumption, and that "electricity aware" individuals show a greater willingness to receive more detailed and customised information on how to save energy at home. Finally, higher ERFL is associated with lower energy consumption according to Kalmi et al. [41].

However, we found two studies which go against these findings. First, Zhang et al. [38] pointed out that being aware of energy consumption does not always lead to lower household energy use. Second, Ali et al. [36] show that despite residents being highly aware of energy-saving practices, there is a disconnect between their awareness and their actions. While people are knowledgeable about energy efficiency actions and are eager to back government initiatives, the absence of such initiatives means that they do not implement those actions in their communities.

Other studies pointed out that EL can help people evaluate potential energy efficiency actions more effectively. Kantenbacher and Attari [42] discovered that energy experts, who typically have higher levels of EL, are better at assessing the energy use of appliances. Dominitz et al. [31] emphasised that understanding how energy is consumed is crucial for planning and implementing energy-saving strategies.

The influence of EL on heating and cooling behaviours is mixed. Brounen et al. [37] reported that energy awareness and literacy do not significantly change heating behaviours, however, their study analysed self-reported energy use. On the other hand, Kvist Svangren et al. [34] found that a good understanding of energy use helps people manage their heating more efficiently, potentially reducing consumption.

Finally, we found that some studies focused on education through training or feedback to increase households' EL and consequently adopt more energy efficiency actions. Regarding training programmes, Dalvi et al. [33] showed that they lead to the adoption of energy-saving actions. Similarly, Valenzuela-Flores et al. [48] demonstrated that training increases EL and reduces household energy consumption. On the contrary, Hoody et al. [32] noted that peer-to-peer training did not significantly reduce consumption.

Feedback mechanisms are another aspect of education programmes. Broberg and Kažukauskas [40] found that less knowledgeable customers often do not understand real energy costs, which affects their willingness to learn and save energy. Mogles et al. [44] highlighted that feedback can lead to behavioural changes and improved EL.

In conclusion, our review suggests that EL can have a role in fostering energy efficiency actions within households. Most studies show a positive link between EL and the adoption of energy-saving practices. They indicate that people who understand energy use and costs are more likely to engage in behaviours such as turning off unused lights, unplugging devices, and optimising appliance use. However, not all research comes to a similar conclusion, with some studies finding no significant connection between EL and energy efficiency actions. This highlights the complexity of translating knowledge into practical behaviour changes. The effectiveness of educational interventions and feedback mechanisms also varies, suggesting the need for tailored approaches.

3.3. Energy efficiency investments

Moving beyond behavioural changes, dealt with in the previous section, here we investigate the extent to which EL empowers people to make informed decisions regarding investments in efficiency. Specifically, the efficiency investments studied include the installation of rooftop solar panels, insulation and retrofitting of the building, and the purchase of efficient household appliances.

Although changing individual behaviour can save energy, investing to improve the overall energy efficiency of the household has a significantly greater impact on reducing overall energy consumption [72]. Many households still refrain from making efficiency investments, despite it being economically optimal, meaning that it would help save money and energy in the long run [73,74]. Insufficient information and lack of knowledge are among the main barriers to rational decision making [75,76]. People are not aware of the long-term economic outcomes of their purchases and do not spend time gathering this information [77].

The following paragraphs describe how EL is related to efficiency investments. We summarise the overall evidence, examine findings on appliance replacement and building retrofits, and highlight the key role of financial decision-making skills. Finally, we outline policy options to close the efficiency gap before moving on to the next chapter.

We found 16 publications which investigate EL as one of the determinants of investments in energy efficiency in households. Out of those, 13 indicate a positive relationship between the two variables, and 3 find no relationship. The 16 studies span three broad classes of investments: appliance replacement, building retrofits and insulation, and small-scale distributed generation. Because individual studies frequently bundle multiple upgrades and use heterogeneous outcome measures, we aggregate at this level for comparability and focus on how literacy skills relate to investment decisions.

Many studies emphasise how EL affects consumer purchasing decisions related to the energy efficiency of appliances. Stikvoort et al. [62] found a positive correlation between energy knowledge and the intention to replace household appliances, suggesting that increased EL can lead to more proactive energy-saving decisions. Olsthoorn et al. [61] identified a cluster of energy-savvy consumers who prioritise high energy class categories (A+++) and durability when purchasing appliances. These consumers are less price-sensitive and more focused on long-term benefits, indicating that higher EL correlates with a preference for energy-efficient products. According to Baikowski [54], it is important to consider the trade-off between higher electricity bills and the cost of purchasing new and more efficient appliances. For example, the overuse of electricity may make it difficult for certain households to invest in more expensive but more energy-efficient appliances.

While specific energy-related understanding directly linked to daily energy use (e.g., knowledge about energy policies or desktop PC consumption) can significantly increase the likelihood of identifying cost-minimising appliances, general energy knowledge or awareness of electricity prices may not [50]. In contrast to the first study, He et al. [60] found that EL, particularly encompassing energy-saving orientations and daily practices, positively and significantly influenced preferences for energy-efficient refrigerators. Individuals with a stronger energy-saving focus were more likely to prefer energy-efficient options. However, specific energy-related understanding, such as knowing the electricity price, was negatively associated with preferences for energy-efficient appliances, possibly indicating a higher price consciousness that made individuals less willing to pay more for efficiency. In essence, both studies demonstrate that EL plays a role in consumer appliance choices, but its impact is highly dependent on the specific goal of the decision. When the goal is to minimise lifetime costs, certain types of energy-related understanding are beneficial, but they might lead to a different choice if cost and efficiency goals are not aligned. Conversely, when the goal is to prioritise energy efficiency and environmental benefits, EL directly supports that outcome.

In addition, EL has been investigated in relation to the likelihood of installing rooftop solar panels and retrofit housing, but the results are mixed. Buchtele et al. [58] observed that individuals who are well-informed about energy believe they can make a positive impact by using renewables. Another study found that knowledge and awareness are critical determinants influencing households' willingness to adopt solar lights significantly. Conversely, a limited understanding of RES and their benefits often leads to hesitation [49]. Being aware of the household's energy consumption can influence the decision to insulate the walls and roof of one's residence [59]. On the other hand, Ropuszyńska-Surma and Węglarz [52] found no confirmation that energy knowledge predicts RES installation at home.

Investing in energy efficiency is not only motivated by concerns about doing good for the environment, but is also a financial decision to seek energy cost savings. Damigos et al. [26] found that individuals with high levels of EL consider a lower subjective discount rate when evaluating future savings in energy expenditures. They are thus more likely to make decisions based on the real return on investment. However, Dharshing and Hille [51] found that neither EL, nor numeracy, nor being an environmentalist influences home efficiency decision-making, as present-bias and perceived risk overshadowed knowledge. More specifically, lifetime-savings framing did not help on average but influenced the most impulsive participants.

Although the majority of studies analysed suggest that EL may be a catalyst for homeowners to make efficiency investments, there are suggestions that this may not always hold true and that other skills may be required for this specific outcome. Lately, researchers have been focusing on ERFL. People with high levels of ERFL may have the skills needed to identify and purchase energy-efficient appliances, thus maximising energy savings while lowering their energy bills in the long term [19]. They can choose appliances that support their energy goals by being aware of the energy consumption characteristics and efficiency ratings of various devices [78]. So far, all studies including ERFL found a positive relation between higher ERFL and investing in efficiency investments.

First, Boogen et al. [57] found that respondents achieving higher ERFL scores in general or attaining higher cognitive abilities scores (i.e., implying greater ability to make beneficial investment decisions) achieve higher energy efficiency in their homes. On the contrary, the level of energy-related knowledge does not seem to be significantly correlated with the level of energy efficiency. Blasch et al. [19] found that higher levels of ERFL are linked to an increase in the adoption of energy-efficient lighting and that the interaction between the energy and financial components is important, since financial literacy alone has no effect. This is in line with the findings from Filippini et al. [78], whose results show that higher levels of ERFL are associated with more rational attitudes toward appliance replacement in households in Nepal, and with Blasch et al. [56], who demonstrated that energy and investment literacy can reduce cognitive biases when choosing household appliances. Asmare et al. [53] found that the willingness of individuals to invest in energy retrofits for multi-apartment buildings is positively correlated with their overall financial literacy, EL, and ERFL. Energy and investment literacy are also associated with a more optimal response to interventions aimed at facilitating the choice of efficient appliances [55].

In conclusion, EL may play a role in empowering people to make informed decisions and invest in energy efficiency. Additionally, ERFL is particularly relevant in this context, especially for decisions related to household appliances. While changing individual behaviours is important for energy savings, investing in optimising equipment and increasing overall household efficiency has a greater impact on reducing energy consumption. A lack of information and knowledge is a significant barrier to rational decision-making, as people may not be aware of the long-term economic outcomes of their purchases. However, investing in efficient technologies may not be sufficient in the coming years. The energy transition requires new behavioural changes and the adoption of technologies that can respond dynamically to these fluctuations. This need for real-time responsiveness and demand-side participation brings us to the next group: energy flexibility actions.

3.4. Energy flexibility actions

In this section, we explore how EL is related to the ability of residential consumers to provide flexibility to the power system. Generally, flexibility refers to an energy system's ability to maintain continuous service during rapid and significant changes in energy supply and demand [79]. Demand-side flexibility is an essential part of overall system-level flexibility [69]. Households can provide this flexibility by adopting and responding to aggregators' signals or dynamic tariffs from their supplier or grid operator [69], shifting energy-consuming activities towards off-peak times [65]. This process requires a high level of attention and proactive decision-making, which is likely to be mentally burdensome and time-consuming [80].

This chapter reviews 7 studies that explore how EL, particularly knowledge of dynamic tariffs, the ability to interpret tariff structures, and an understanding of flexibility concepts, is related to households' willingness and capacity to shift their electricity use (3 studies), or adopt real-time pricing (4 studies). We also identify gaps in the existing literature and discuss how targeted education and engagement strategies may unlock the flexibility potential of residential consumers.

Many European Union countries have adopted static time-of-use electricity tariffs [81]. However, dynamic pricing is becoming increasingly important as it provides real-time signals about energy availability and events that may require a demand-side flexibility [82]. In some countries, such as Finland, about one in three households opted for real-time electricity pricing [83], whereas others, including France [84] and Germany [85], remain at an earlier stage of adoption. EL could play a role in increasing the understanding and the adoption of dynamic tariffs, as a survey by Reis et al. [68] suggests. They found that higher levels of energy and graphical literacy were associated with a higher willingness to adopt time-differentiated tariffs. Additionally, most respondents were unable to demonstrate the ability to correctly read graphs or how to calculate the energy costs associated with time-differentiated tariffs. Similarly, the study on dynamic tariffs by Dütschke and Paetz [66] suggests that consumers are more willing to adopt a dynamic tariff if they are familiar with this concept or have already experienced it. However, this is not likely, given the low rate of implementation. This study also highlights that the economic advantages of these kinds of tariffs are most frequently unclear, thus lowering consumer willingness to engage. Similarly, Ruokamo et al. [69] suggest that difficulties understanding contracts, combined with risk aversion, is a reason why customers do not participate in real-time pricing schemes. Finally, Nilsson and Bartusch [63] show that time-differentiated tariffs primarily benefit a narrow subgroup of consumers with the knowledge, interest, and ability to understand and adjust their electricity use accordingly, limiting their reach to the broader population. To the authors' best knowledge, none of the other state-of-the-art papers deal directly with the link between EL and willingness to adopt dynamic tariffs. However, it is worth noting that understanding and awareness of tariffs regarding one's energy bills is a component of EL scales in several papers [64,86,87].

Flexibility can also be provided by shifting electricity consumption when needed [88]. The lack of EL has been identified as one of the barriers to the shifting of routine activities, since consumers underestimate the energy consumption of short, daily activities, such as taking a shower [64,65]. Additionally, familiarity with the smart grid is also a factor that could favour household flexibility. It was found to have a positive influence on the willingness to change energy use patterns, such as postponing the start time of appliances and turning off heating or air conditioning appliances [67]. This is not a one-sided relationship, with some studies indicating that EL emerges as a side effect of flexibility pilot projects. This happens due to the information campaigns combined with these pilots [89,90].

EL could improve the acceptance of dynamic tariffs and the provision of flexibility. Given the growing importance of demand-side flexibility provision, we believe that the impact of EL on flexibility is under-researched. Energy education can be a relatively low-cost and scalable strategy for promoting changes in energy use behaviour, for example, via providing more and clearer information on the portals of the energy supplier or the grid operator. While such initiatives may not require direct financial incentives, they can still generate meaningful system-level benefits by enabling more informed and timely consumption decisions. This highlights the importance of further exploring both the potential and the cost-effectiveness of demand-side flexibility measures centred on consumer awareness and engagement.

3.5. Energy flexibility investments

Participating in flexibility initiatives by manually reacting to dynamic electricity tariffs and shifting consumption represents a significant mental and organisational burden for residential consumers [91]. To reduce this burden, some consumers invest in flexibility technologies [29]. These are systems that use algorithms and real-time data to optimise energy consumption, reducing the organisational burden on consumers and improving overall efficiency [92]. For example, a smart thermostat can automatically lower heating or cooling during peak demand periods, while a smart charger can delay electric vehicle charging until off-peak hours [93]. Acceptance of direct load control (DLC) is also a form of flexibility which requires investing in automation. With DLC, consumers authorise a third party (e.g., energy supplier, network operator) to remotely control specific household devices [94]. However, household consumers are reluctant to accept this out of concerns of losing control and comfort [95]. We found 3 papers suggesting that EL and flexibility investments are connected.

One study on Luxembourgish households indicates that EL is related to a higher intention to accept DLC for heating and electric vehicle charging [71]. Furthermore, Rahman et al. [70] suggests that EL programmes explaining flexibility concepts and their tangible benefits can strengthen consumer engagement in prosumer flexibility initiatives. Similarly, Chadwick et al. [25] highlights that households with greater EL are more likely to adopt new energy technologies (such as smart meters, storage batteries, or smart home technologies) due to their understanding of the benefits and functionalities of these technologies. Conversely, a lack of EL can act as a barrier, as perceived complexity can cause hesitation when considering the adoption of new technologies.

Despite its potential to significantly enhance demand-side flexibility, there is insufficient research on this topic. If further research indicates that EL or ERFL support investments in flexibility-enabling technologies, this would provide a clear rationale for prioritising educational measures to boost residential flexibility. This gap in research highlights the need for the EL community to focus more on this area, ensuring that the benefits of flexibility are fully realised and integrated into energy systems.

3.6. Methodological approaches in energy behaviour and energy literacy research

Understanding the intricate dynamics of human interaction with energy systems requires a diverse and robust set of research methodologies. This section outlines the various research paradigms, study designs, and analytical techniques employed across these studies.

3.6.1. Research paradigms and approaches

Research in energy-related behaviour often operates within established scientific paradigms, adapted to the specific challenges of human-energy interactions. Several studies explicitly adopt a positivist research paradigm. This approach aims to objectively identify relationships and establish predictive power, often involving the development of causal effect models and statistical hypothesis testing. For instance, one study developed a baseline model to explain the relationship between EL, attitude towards energy, personal energy value, and energy savings behaviour, testing hypotheses using Variance Based Structural Equation Modelling [39].

Some studies are exploratory, such as a single-case study of prosumer flexibility in the Finnish electricity ecosystem [70], aiming to generate new insights rather than test hypotheses [65]. Others use an explanatory design to investigate causal relationships among variables, like the one assessing ERFL and trust on apartment owners' willingness to invest in retrofits [53].

Qualitative methodologies are mostly used for exploratory studies, particularly when the research field is nascent or when a nuanced, context-sensitive understanding of complex causal links is needed. Examples include exploring human influences on technology adoption or understanding motivations behind consumer preferences [25]. Interviews are frequently used, with semi-structured formats allowing exploration of specific topics while remaining flexible to follow new leads and discover unique responses [49]. One study used semi-structured interviews to explore behavioural tendencies, energy knowledge gaps, and attitudes among low-income public housing residents [35]. In-depth interviews can delve into motives and barriers behind preferences [66]. Think-aloud sessions are used in conjunction with choice tasks to gain instantaneous and unfiltered insights into participants' cognitive processes [42]. Focus group discussions are used to capture diverse community perspectives, foster participatory engagement, and explore complex or contested issues [34].

Quantitative research approaches are employed when mediation models require numerical data and statistical testing of hypotheses, or for large-scale surveys to achieve wider generalisability. This includes studies examining consumer preferences, energy efficiency, and the impact of information [55]. These studies sometimes use smart meter data, collected hourly or in real time, to provide unobtrusive measures of electricity consumption to assess actual energy use and reactions to programmes [44]. This data can be crucial for assessing the impact of dynamic pricing or feedback interventions.

Some studies combine both qualitative and quantitative methods through a mixed-methods approach to provide richer data and support findings from multiple angles. This allows for the contextualisation of quantitative data and the quantification of qualitative insights, particularly useful for understanding user perceptions and behaviours related to digital interventions like interactive electricity bills [31].

3.6.2. Study designs

A variety of study designs are utilised to address different research questions and objectives. Many use surveys and questionnaires to collect data on attitudes, perceptions, behaviours, and socio-demographic characteristics from a large pool of participants. Some surveys incorporate specific tools like the Energy Literacy Questionnaire [16] to measure cognitive, affective, and behavioural domains. For example, a study on EL in Ghana used a survey-based questionnaire to solicit data from 250 professional workers [39]. Another study relied on incentivised representative survey data collected from apartment owners in Lithuania to examine the effect of ERFL and trust on willingness to invest in retrofits [53]. Among them, Stated Preference Surveys and Choice Experiments are used to elicit consumer preferences and willingness-to-pay for certain attributes or measures. These involve presenting hypothetical scenarios and choices (e.g., between energy-efficient appliances or load management programs) [26,69]. Contingent Valuation experiments are a type of stated preference survey used to estimate participation probability and subsidy costs [61].

Other studies use field experiments or Randomised Controlled Trials to test the effectiveness of interventions in real-world settings. Participants are randomly allocated to different treatment groups (e.g., control, information, feedback, different tariff structures, or decision aids) to control for confounders and identify added costs or effects. Examples include testing dynamic electricity pricing incentives [66], energy information and education projects [33], decision aids for appliance choice [55], and digital energy feedback systems [44].

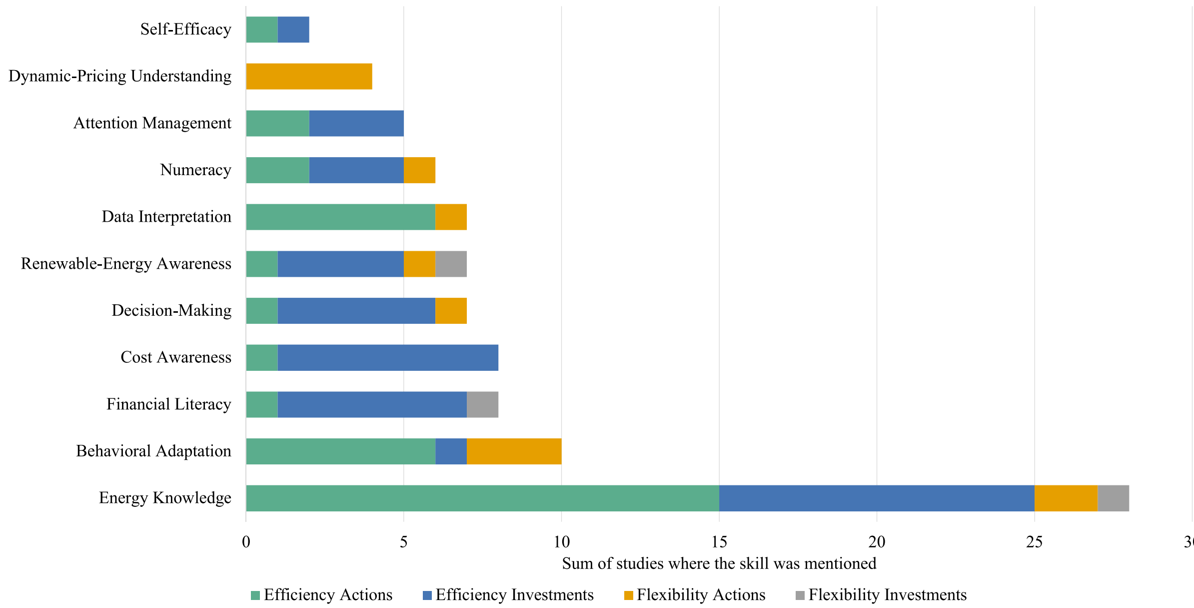

Fig. 4. Energy literacy skills per group of behaviours.

Some studies used a living lab setting for long-term qualitative studies, such as investigating the usage of Home Energy Management Systems over an extended period (e.g., three years with seven households) [46].

Finally, systematic reviews and meta-analyses involve a methodologically rigorous process to synthesise findings from a wide range of disparate literature. Meta-regression was applied to explain the impact of including a broader range of influences on the behavioural realism of models [25]. One review focused on human influences on household adoption and rejection of energy technology based on 181 peer-reviewed papers [25].

3.7. Skills in energy literacy

To examine how different competencies have been studied in association with energy-related behaviours, we categorised eleven distinct skill groups and assessed their prevalence across the four behaviour groups: energy efficiency actions, energy efficiency investments, energy flexibility actions, and energy flexibility investments. Our quantitative analysis of 45 studies revealed pronounced alignments between particular skills and specific outcomes. Fig. 4 shows how many times each skill has been found in the studies, divided per group.

In the literature on energy efficiency actions, namely behaviours such as reducing consumption or responding to feedback, the most common skills are energy knowledge (appearing 15 times), followed by data interpretation (appearing 6 times) and behavioural adaptation (appearing 6 times). In their 2023 study, Appiah et al. [39] demonstrate that a basic grasp of energy concepts combined with focused decision making leads directly to measurable savings. Gaskell and Pike [17] showed that interpreting feedback charts and maintaining concentration on energy information reduces household consumption. Dominitz et al. [31] found that the ability to read bills and foraging for relevant information prompts immediate adjustments in user behaviour, while Dalvi et al. [33] revealed that even simple cues, such as switching off appliances at the plug, depend on basic numeracy and sustained attention to yield energy savings.

Research on energy efficiency investments, which involves decisions around retrofits or appliance upgrades, most often features energy knowledge (appearing 10 times), cost awareness (appearing 7 times) and financial literacy (appearing 6 times). Asmare et al. [53] report that participants who can calculate payback periods and distinguish actual from perceived costs are more inclined to invest in house retrofits. Blasch et al. [56] and Blasch et al. [55] highlighted that optimising life cycle costs through investment calculations underpins the adoption of efficient lighting and appliances. Damigos et al. [26] further confirm that applying portfolio theory analogies, such as stock diversification, boosts uptake of energy-efficient refrigerators and insulation measures.

Energy flexibility actions, which involve time shifting of consumption, most commonly align with dynamic pricing understanding (appearing 4 times), then behavioural adaptation (appearing 3 times) and energy knowledge (appearing 2 times). Dütschke and Paetz [66] demonstrate that comprehension of real-time and critical peak tariffs is essential for users to shift loads. Nilsson and Bartusch [63] show that mapping tariff schedules to activities such as electric vehicle charging yields significant peak reductions, and Walker and Hope [65] confirm that understanding appliance energy intensity, paired with modified routines, produces measurable demand side flexibility.

Finally, investments in flexibility technologies, such as smart grid-enabled appliances, community renewables or storage systems, involve energy knowledge (appearing 1 time), renewable energy awareness (appearing 1 time), and financial knowledge (appearing 1 time) Andolfi et al. [71] shows that a mix of grid and renewable energy awareness is associated with a higher likelihood of investing and accepting DLC.

4. Discussion and limitations

This section presents and discusses the main findings of the review in relation to the existing literature. It first interprets the results by outlining how energy literacy is associated with distinct groups of household behaviours and by identifying the specific skills that underpin these relationships. The discussion also reflects on how these findings compare to previous frameworks and contribute to the conceptual understanding of energy literacy. The second part of this section addresses the main limitations of the study and outlines directions for future research aimed at refining the conceptual and methodological foundations of this field.

4.1. Interpretation of the results

As a result of our review, we propose a classification framework of the various energy-related behaviours which can be influenced by EL. The groups of behaviours are defined as follows. The first group relates to the implementation of energy efficiency actions. These are associated with basic knowledge about energy-saving practices and the energy consumption of different household equipment items. We found that 14 out of 19 studies support this relationship. The second group features energy efficiency investments. These are linked to more finance-related skills, such as cost awareness or the ability to make life-cycle cost calculations. This relationship is supported by 13 out of 16 studies. The third group consists of the implementation of energy flexibility actions. These are related to the understanding of flexibility concepts, such as time-differentiated tariffs and peak times. We found that 7 out of 7 studies support this relationship. Finally, the fourth group features investments in flexibility technologies. These may be associated with the same skills as the third group, plus the life-cycle cost knowledge described in the second. We found 3 studies indicating this relationship.

This study was structured around three research questions: which energy-related behaviours have been studied in connection with EL (with a focus on flexibility), how EL is associated with these behaviours, and which skills are most relevant in shaping them. By reviewing 45 peer-reviewed studies, we have developed a new classification framework and provided evidence-based responses to each of these questions.

To address the first research question, we identified four main groups of behaviours which have been studied in connection with EL. These include actions and investments that aim to improve energy efficiency, and actions and investments that enhance demand-side flexibility. This framework captures both well-established behaviours, such as reducing household energy consumption, and emerging practices related to flexible electricity use. While energy efficiency has received considerable attention, the role of EL in shaping flexibility-related behaviours remains comparatively underexplored.

Second, we examined how EL is related to each of these behaviour types. The majority of studies report a positive link between EL and energy efficiency actions. Consumers with a better understanding of energy use are more likely to adopt energy-saving habits and to invest in efficient technologies. For investment behaviours, financial skills may play an important role, suggesting that ERFL is a more suitable predictor in these cases, especially when deciding on household appliances. Regarding flexibility, EL appears to increase the likelihood of understanding and adopting dynamic pricing mechanisms and shifting consumption to off-peak periods. However, evidence on flexibility investments is limited. Three studies directly link EL to the adoption of flexibility technologies and DLC acceptance, which highlights the need for further empirical research in this area.

Third, our review identified the skills that have been studied in association with each behaviour group. For energy efficiency actions, energy knowledge predominates, with data interpretation and behavioural adaptation supporting measurable savings through bill reading, basic numeracy, and sustained attention. For efficiency investments, energy knowledge combines with cost awareness and financial literacy, where skills like life-cycle cost calculation underpin some adoption decisions. Flexibility actions depend most on understanding dynamic pricing, complemented by behavioural adaptation and general energy knowledge, which help households align routines and high load activities with tariff signals. Investments in flexibility technologies could be closely associated with financial knowledge, together with awareness of renewables and grid operation.

This paper provides a structured and detailed framework that links EL and related skills to a range of household behaviours. It mainly builds upon the works of DeWaters and Powers [16], Van Den Broek [18], and Martins et al. [14]. As in these studies, we highlight the importance of knowledge about energy consumption and efficiency. This foundational knowledge is crucial for promoting energy-efficient behaviours, aligning with the cognitive component emphasised in existing frameworks. Both our classification and the study of DeWaters and Powers [16] highlight the direct connection between EL and specific behaviours. Additionally, similar to the typologies of Van Den Broek [18] and Martins et al. [14], our framework incorporates financial literacy, recognising its pivotal role in facilitating investment-related behaviours. Van Den Broek [18] suggests that it is unclear whether financial knowledge affects household energy consumption. In our case, the relevance of ERFL is especially related to the investment in energy-efficient household appliances; these findings are not necessarily contrasting, as higher efficiency does not necessarily translate to lower consumption [96], and the relationship between ERFL and the investment in other technologies is still unexplored.

Our classification framework also introduces unique elements that set it apart from existing frameworks. A notable distinction is the explicit differentiation between energy-efficient and flexible behaviours. This differentiation is particularly relevant in the context of the energy transition and the growing need for demand-side flexibility. While existing studies primarily focus on energy-efficient behaviours, our classification framework addresses the emerging importance of flexibility. Furthermore, we categorise behaviours into actions and investments, providing a more detailed understanding of how different types of behaviours are associated with EL. This categorisation offers a finer degree of granularity compared to the broader focus seen in other works.

This study addresses a significant gap in the EL field, which has lagged behind energy flexibility research for years, particularly from a technical perspective. This delay is notable, as flexibility provision has been a key area of energy research for at least a decade [97]. By integrating flexibility-related concepts, we aim to push the research on EL in this direction as well. Without proper literacy from a flexibility perspective, the actual provision of flexibility might be heavily underutilised [67], rendering much of the research around it unnecessary. This addition is crucial for understanding how EL can support the evolving needs of the power system, especially in the context of RES integration and grid stability.

4.2. Limitations and future research

Finally, we must acknowledge the limitations of this study. First, publication bias may have influenced our findings, as studies with insignificant or contrary results are less likely to be published [98]. This bias can skew the overall understanding of the topic, as only positive or significant results are more prominently represented [99]. Second, our study relied solely on the Scopus database, which, while comprehensive, may not encompass all relevant literature. The use of a single database is advantageous for consistency and ease of data management, but it limits the breadth of the literature reviewed.

Third, conceptual and definitional inconsistencies across the reviewed studies posed a challenge to synthesis. While our review adopted an inclusive and multidimensional definition of EL, the studies we analysed used a variety of interpretations and measurement tools. Some treated EL as a unidimensional knowledge construct, others focused on affective or financial aspects, and only a few adopted multidimensional frameworks. This heterogeneity complicates direct comparison and limits the extent to which our findings can be generalised across contexts. Furthermore, the heterogeneity in study design across the sample restricts the strength of the conclusions we can draw. The 45 studies included in our review varied widely in terms of methodology, sample size, and analytical depth. Several relied on self-reported behaviour or cross-sectional surveys, which may introduce bias or limit the ability to infer causality. In particular, the positive associations reported between EL and household behaviours may be overstated if not supported by robust empirical designs or validated behavioural measures. Our experience of conceptual and method heterogeneity mirrors the call by Goodman and Marshall [100] to grapple with methodological fragmentation and the need for clearer frameworks.

Fourth, our classification of behaviours into four distinct groups, actions and investments related to efficiency and flexibility, helped organise the findings; however, it may obscure the complexity of household decision-making. Many behaviours are interdependent or occur within broader social and infrastructural contexts that are not fully captured by this taxonomy. Moreover, few studies examined behaviour over time or in response to changing technologies or policies, limiting the dynamic validity of the behaviour categories.

Future research should address several limitations identified in this review. To mitigate publication bias, future studies could include grey literature, project reports, and unpublished evaluations, which may contain null or negative findings often absent from peer-reviewed journals. Empirical work is particularly needed to investigate investments in flexibility technologies, currently represented by only 3 studies in our sample. Longitudinal, experimental, or mixed-method approaches would help explore how EL and ERFL influence the uptake of smart technologies and automated systems. Expanding the range of databases beyond Scopus and including non-English sources would improve the breadth and diversity of future reviews. At a conceptual level, standardised definitions and measurement tools are essential to enable comparability across studies. Methodologically, there is a need for stronger designs, including experimental and longitudinal studies that move beyond self-reported behaviour and can support causal inference. Additionally, future research should better capture the complexity and interdependence of household decisions, examining how behaviours co-evolve, respond to policy or market signals, and interact within broader socio-technical systems. This would support the development of more nuanced frameworks and more targeted, evidence-based interventions.

5. Conclusions

This study has explored the various energy-related behaviours that have been examined in relation to EL. It has also highlighted the association between EL and these behaviours and identified the skills that effectively shape them.

We conducted a systematic literature review, which included a comprehensive search strategy and a detailed screening process, resulting in the selection of 45 studies that provided valuable insights into the impact of EL on household energy consumption behaviours. Our findings indicate a positive relationship between EL and energy-efficient behaviours. Higher EL is associated with more proactive behaviours, from simple daily habits like turning off lights to significant investments in energy-efficient appliances and home retrofitting. Financial literacy is also linked to some of these investments. However, the connection between EL and flexibility behaviours (such as adopting dynamic tariffs or DLC) remains an under-explored but promising area for future analysis.

This research contributes to the broader understanding of how enhancing EL can drive sustainable energy consumption behaviours in households. By emphasising the positive association between EL and energy efficiency and flexibility actions and investments, our study highlights the potential for targeted educational programmes to support the energy transition. Additionally, our review identifies a critical gap in the research on flexibility behaviours, highlighting the need for further investigation in this area. Future research should examine the link between EL and clearly defined flexibility behaviours, such as off-peak electric-vehicle charging, heat-pump pre-heating and setback, shifting laundry and dishwashing cycles, responding to dynamic tariffs, and opting in to DLC.

Educating households about flexibility can be inexpensive at the margin when materials are delivered digitally, for example, short e-learning modules, in-app tooltips, tariff calculators, and personalised bill feedback that reuses existing data pipelines. Nevertheless, costs still need to be considered because low marginal delivery does not remove programme design, targeting and evaluation costs, nor user time costs. Future studies should therefore report both effectiveness and cost-effectiveness, for example, costs per additional kilowatt-hour shifted or per percentage point of peak reduction.

A further priority is to standardise how EL is defined and measured, since current studies use heterogeneous instruments. We recommend a core instrument focused on objective knowledge that covers tariff comprehension, basic numeracy, interpretation of bills and feedback, cost awareness, understanding of dynamic pricing, and self-efficacy in applying energy information. The instrument should include clear scoring rules, validated short and long forms for surveys and experiments, and preregistered item banks with shared documentation to improve comparability across studies and over time.

In conclusion, strengthening EL remains a promising route to support efficient household consumption and demand-side flexibility. By testing specific flexibility behaviours with rigorous methods, reporting cost-effectiveness, and adopting a standardised measurement, future work can clarify when and for whom literacy interventions shift loads and reduce peaks, thereby contributing to a more sustainable and resilient energy system.

CRediT authorship contribution statement

Laura Andolfi: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Ivan Pavić:** Writing – review & editing, Validation, Supervision, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Grammarly, Microsoft Copilot, and ChatGPT to improve readability and language. After using these tools, the authors reviewed and edited the content as needed and took full responsibility for the publication's content. An English mother-tongue proofreader also reviewed this text.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Laura Andolfi reports financial support was provided by Creos Luxembourg. Ivan Pavic reports financial support was provided by Creos Luxembourg. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

No data was used for the research described in the article.

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