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Not peer-reviewed version

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Posted Date: 3 October 2023

doi: 10.20944/preprints202309.2079.v1

Keywords: Energy literacy; energy reviews; energy-related knowledge; energy transitions; energy education.

 doi:10.20944/preprints202309.2079.v1

Review

Energy Literacy: A Systematic Review of Scientific Literature

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Abstract: The world is facing an energy crisis. Governments are seeking to provide universal energy access and guarantee energy security while trying to mitigate climate change. One possible solution is energy transitions towards low carbon energy systems. Among other things (physical infrastructure, public policy and regulatory enablers and knowledge and capacities) changes in the energy systems require a well informed and participative citizenship. Within this context the concept of energy literacy appears. Energy literacy is the understanding of how energy is generated, transported, stored, distributed, and used, awareness about its environmental and social impacts and the knowledge to use it efficiently in the different sectors of the economy. This paper provides a systematic literature review in the Web of Science's Core Collection. Most of the work done around energy literacy addresses its evaluation among different groups, particularly students at different levels, and the construction, application, and evaluation of tools for improving energy literacy. Other frequently studied issues are the influence of energy literacy in decision making, its drivers and conceptual research about the topic. Energy enables citizens to effectively contribute to energy efficiency and sustainable development, nevertheless energy literacy is not strongly correlated to energy consumption habits.

Keywords: energy literacy; energy reviews; energy-related knowledge; energy transitions; energy education

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1. Introduction

Energy is an essential element in the lives of people and societies. Domestic energy services are used to cook and preserve food, keep medicines refrigerated, media and information, and provide lighting, entertainment, and comfortable indoor temperatures. Energy services also enable productive work and allow people to carry out all types of activities quickly and efficiently, dedicating significantly less effort to complete them.

On a larger scale, energy drives economies and sustains societies (UNEP, 2023). Energy is fundamental for human development, key to addressing several of the challenges that humanity faces and necessary to achieve the United Nations agenda for 2030 (UN & UN-Energy, 2022). On the other hand, around 75% of greenhouse gas emissions come from the energy sector, highlighting that the production and use of energy are the main drivers of current climate change (UNDP, 2023).

Climate change refers to long-term variations in temperature and weather patterns. Climate change has serious negative effects globally, making it one of the most urgent problems that people and countries face today (UN, 2023). It is true that these types of changes in weather patterns have occurred naturally throughout history; however, all scientific evidence indicates that human activity is the main cause of current climate change. Particularly, the burning of fossil fuels such as coal, oil, and natural gas (UN, 2023).

Despite its importance, governments and civil society need to take action not only to combat climate change, an environmental issue related to energy; but to take actions that also address political and economic issues related to energy, such as energy security and access to domestic energy services (Heffron et al., 2015). Frequently, the instruments used to achieve goals related to these three issues compete in a phenomenon called Energy trilemma (Gunningham, 2013) which can be defined as "the conflicting goals that governments face to ensure energy supply, provide universal access to energy services and promote environmental protection" (Figure 1) (Gunningham, 2013).

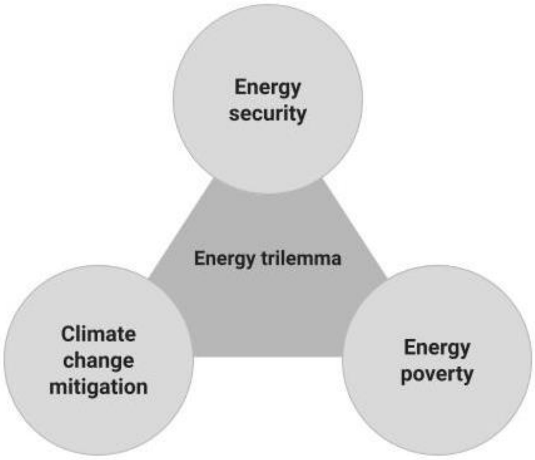

Figure 1. The Energy trilemma.

The lack of access to energy services is known as energy poverty. It occurs when a household cannot ensure a level of domestic energy services that would allow them to fully participate in the customs and activities that define membership in a specific society (Thomson et al., 2019). In the trilemma, energy poverty (sometimes included in the broader concept of energy justice) is the aspect that generally receives the least attention (Tomei & Gent 2015). Although the incidence and intensity of the phenomenon, as well as the degree of study, vary considerably from one country to another, Latin America seriously suffers from energy poverty (Thompson et al., 2022).

In general terms, energy security is the supply of adequate and stable energy to meet the demand of all economic sectors in a country (Kanchana &You have a sack 2015). Furthermore, the energy supply must be reliable, uninterrupted, sufficient, and affordable; and for countries that export energy products, energy security also considers the certainty of demand from abroad (Kanchana &You have a sack 2015). Additionally, the flexibility of systems and the diversification of energy products play an important role in energy security.

Global surface temperature increased by a total of around 1 ºC from the period 1850-1900 to the period 2010-2019 due to human activity (IPCC, 2021). Russia, the world's third largest oil producer, announced in February 2023 that it would reduce its oil production starting in March of the same year by 500,000 barrels per day (Reed, 2023). Despite advances in recent years in access to modern energy services, about 75 million people who recently gained access to electricity could lose the ability to pay for it, while 100 million people could return to using traditional biomass for cooking (IEA, 2023).

Currently, energy systems around the world are under pressure and governments are seeking to achieve universal access to energy services, ensure energy security and limit climate change, all while immersed in a global economic recession, suffering the consequences of the Covid-19 pandemic and during Russia's war in Ukraine, which may further escalate and exacerbate the global energy crisis. On the other hand, the effects of the crisis on energy markets have led to a decrease in collaboration between countries, which is a key element to achieving a net zero emissions energy system (IEA, 2022).

The energy crisis has also highlighted the importance of energy efficiency and behavioral measures in keeping energy supply and demand in balance. In this sense, the International Energy Agency (IEA) recognizes the crucial participation of governments, companies, and citizens to keep the increase in global temperature below 1.7 ºC in the Scenario of Announced Commitments and below 1.5 ºC in the Net Zero Emissions Scenario in the year 2100 (IEA, 2022). Effectively addressing the current energy crisis will require, among other things, a well-informed and participatory citizenship.

In the context of citizenship, information plays a key role for people to acquire knowledge and to find out about events that are taking place, both in their immediate environment and around the world. Access to information allows citizens to know their rights, educate themselves and find out about health services, housing, employment alternatives and public programs and policies (Ramos, 2015). The information also enables people to understand domestic energy use, its importance for economic development and its environmental impacts.

Information enables increasing people's capacity for action in public matters, such as electoral processes, as well as in private matters, such as how to acquire and use energy in homes. An informed citizenry will be able to participate effectively in events of public interest, including the efficient use of domestic energy and the transition towards a low-carbon energy matrix.

To refer to citizens informed in terms of energy, the concept of energy literacy is used in academic literature. DeWaters and Powers, authors with great influence in the research field of energy literacy, define it as "the citizen understanding of energy that encompasses broad knowledge of the subject, as well as affective and behavioral aspects" (DeWaters & Powers, 2013). According to Van den Broek (2019), an energy literate person can be someone who knows the energy consumption of their appliances, what actions can save energy in their homes, how to make energy efficient decisions or knows the relationship between energy consumption and climate change. Thus, a person can be energy literate in one or more aspects and not be so in others. In another definition, Wang and collaborators define energy literacy as the ability of people to understand the roles of energy and energy knowledge to ensure environmental sustainability (Wang et al., 2021).

This work seeks to answer the research question What are the aspects and methodologies of energy literacy that are addressed in the scientific literature? Its contribution to the field of study is related to four main points: 1) There are few systematic reviews on energy literacy in the literature. This article seeks to contribute to the topic approaching it differently, paying special attention to the main objective of the studies. 2) The information shown has the potential to contribute to closing existing gaps in energy literacy, such as the lack of information on the subject. 3) Finally, Latin America has few publications on energy literacy. In particular, the review found only one article that explicitly mentions that it was carried out in the Mexican context. This article can be used as a starting point to design and implement tools that contribute to increasing energy literacy in the Mexican and Latin American population.

Regarding its limitations, the bibliographic review was carried out on the platform Web of Science, therefore the documents that are not included in this database were outside the scope of the work. This is particularly true for gray literature, that is, information that is not published in the regular media. Also, classifying documents according to their main objective is not a simple task, especially because they often have different objectives with similar importance. The classification is done in an illustrative manner, with the aim of making information consultation more accessible. Energy literacy is dependent on economic, cultural, and sociodemographic aspects and its evaluation is complicated. Grouping papers together to present them systematically undermines the diversity of studies, perspectives, and findings, which in turn diminishes the impact of the review. The information presented in this article has the potential to positively influence research related to energy literacy.

The article is structured as follows: in section 2, the methodology followed to carry out the bibliographic review is described. In section 3, the results of the review are presented, categorized according to the main objective of each reviewed article. The categories included in this section are Reviews, Measurement, Improvement Tools, Influence and Other Lines of Research. Finally, in section 4 the study of energy literacy is discussed, what is next for this field of study and the most relevant conclusions are presented.

2. Materials and Methods

The citation mining methodology is based on the application of a combination of bibliometric techniques and text mining for the analysis of bibliographic data (Kostoff et al., 2001; del Río et al., 2002). In this case of study, the objective has been defined as research articles on energy literacy with the following search criteria TS=("energy literacy" OR "energy alphabet*") written until February 2023 that are part of the Web of Science's Core Collection. These include: Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI), Conference Proceedings Citation Index - Sciences (CPCI-S), Conference Proceedings Citation Index – Social Sciences and Humanities (CPCI-SSH), Book Citation Index – Sciences (BKCI-S), Book Citation Index – Social Sciences and Humanities (BKCI-SSH) and Citation Index from emerging sources (ESCI).

This set was analyzed using the computational tool that our research group has developed for this purpose, a text mining algorithm (Cortés et al., 2008). While the bibliometric stage is performed exclusively by counting similar data from different fields in said bibliographic records, the text mining stage uses an entropy-based algorithm to find the most relevant words in the record summaries. This algorithm is based on research conducted by Ortuno et al. (2002). The distance between two occurrences of a particular word appearing in the text of an abstract was compared to the standard deviation of all words in all abstracts. A normalized standard deviation greater than 1 indicates that the word distribution within a particular abstract is not random, allowing us to determine which words or strings of words can be considered relevant to that text.

The reasoning behind this assumption is that standard deviation is an indicator analogous to entropy (Reiss et al., 1986) and can sometimes play a role as a measure of order (or disorder). The advantage of this technique is that it does not require a laborious review of individual words to extract keywords from a text, but rather provides a prepared list of the most frequently occurring words and word strings, whose distribution within a text is not random and therefore is likely to be significant. This technique has been used to analyze highly visible science topics (Russell et al., 2007).

3. Results

As of February 2023, 138 articles that talk about energy literacy (defined according to the criteria mentioned in the Materials and Methods section) were found on the platform Web of Science. In the review, 6 categories were identified: Reviews, Measurement, Improvement tools, Influence, Other lines of research and No direct relationship, as can be seen in Table 1. Additionally, 7 documents were found whose abstract cannot be read from the platform. As the table shows, each category is subdivided according to the main research objective pursued in the work, identified through the information provided in the abstract.

Table 1. Categories and main research objective of the analyzed articles. Information until February 2023.

Category	Main research objective	Number of documents
Reviews	Review	2
Measurement	Adaptation of measures	1
	Comparison	2
	Construction of measures	6
	Assessment	35
	Measures evaluation	2
Improvement tools	Evaluation of improvement tools	17
	Improvement tools	13
Influence	Model construction	6
	Direct influence	15
Other lines of research	Education	8
	Factors	6

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	Conceptual research	10
No direct relationship	No energy literacy	8
Empty	Empty	7

It is important to mention that several articles can be classified into more than one subcategory; however, they were grouped according to the main objective defined in the work abstract, sometimes implicitly. A clear example of this is given in the Measurement category, where several documents evaluate the energy literacy of specific groups of people, thus placing themselves in the Evaluation objective, while the authors also construct the evaluation measures, generating the alternative to place them in the Construction of measures objective. This is the case of most of the works that evaluate energy literacy, since within the research methodology the way to evaluate it is also designed. As mentioned before, for subdivision we take just one of the objectives.

3.1. Reviews

Of the articles analyzed, only two have as their main objective to carry out reviews of the scientific literature. In the first of them, published in 2019 (Van den Broek, 2019), a bibliographic review of the different related approaches and methodologies is completed. The author identified four general approaches: device energy literacy, action energy literacy, financial energy literacy, and multifaceted energy literacy. This is one of the few articles that discusses approaches, and not aspects of energy literacy as most literature does.

In the second review article, published three months later in February 2020 (Martins et al., 2020a), the authors also carry out a literature review on energy literacy. Unlike the first, this review is built around the work of DeWaters and Powers (2013) on the aspects that energy literacy encompasses: knowledge, emotional or affective and behavioral. Additionally, the authors identified financial knowledge as another important aspect of energy literacy.

3.2. Measurement

Until the date of the review, 47 documents were found whose main objective is related to the measurement of energy literacy. These were subdivided into five classes of objectives: Adaptation of measures, Comparison, Construction of measures, Assessment, and Measures Evaluation. Of the group of documents analyzed, only one had the main objective of adapting a methodology (Güven et al., 2019), in which an energy literacy evaluation scale originally designed in English is adjusted to the Turkish context. The reliability of the tool is also validated.

On the other hand, two documents made a comparison of energy literacy, one between different universities in the same country (UK) and another between different countries (UK and China). Both works have several authors in common, including the main author. In the first (Cotton et al., 2018) a comparison of energy literacy is carried out between university students in different positions of the Green league in the United Kingdom; while in the second, energy literacy is evaluated among students from universities in China and the United Kingdom (Cotton et al., 2021).

Regarding the Construction of measures, DeWaters and Powers (2013) propose explicit criteria to develop measurable objectives related to energy literacy in three dimensions: cognitive, affective, or emotional and behavioral. At the same time, these authors and other colleagues (DeWaters et al., 2013) published their work on the development of a measurement scale for evaluating energy literacy, and its application to middle and high school students in the United States. The instrument developed in these two works used psychometric principles of educational and social psychology, making the work have, since its publication and to date, a significant influence on the study of energy literacy; and several subsequent publications derive from the work of DeWaters, Powers, Qaqish y Graham.

Continuing with the objective Construction of measures, Turner et al. (2014) designed a survey to evaluate energy literacy related to electricity; Yusup et al. (2017) built a structure for the energy literacy assessment of future physics teachers; Martins et al. (2020) developed an energy literacy index as well as an index for each of the dimensions knowledge, financial calculations, attitudes and behavior; and Das and Richman (2022) built and applied a public instrument to measure energy literacy in three dimensions: cognitive, attitudinal and behavioral. It should be noted that in some works, such as that of Das and Richmam and that of Martins et al., the affective or emotional dimension is replaced by that of attitudes, although the criteria that characterize them are similar.

Most articles on energy literacy evaluate it among different groups of people, notably focusing on students of different levels. As mentioned above, in several of the works the tools to carry out the evaluation are also designed. Table 2 shows the 35 documents with the main objective of evaluating energy literacy identified in the literature review. The table shows the region, country, state, or city; the population evaluated; and the reference to the document. Of these, several analyze the factors that influence energy literacy (in italics the reference in the table) including the gender or sex of the people evaluated (in italics and bold the reference in the table), of which the work of Lee et al. stands out.

Table 2. Documents with the main objective of evaluating energy literacy. Data until February 2023.

Region	Population	Reference
New York State	Middle and high school students	DeWaters y Powers, 2008
New York State	Middle and high school students	DeWaters y Powers, 2011
New York State	Secondary students	DeWaters y Powers, 2011
State of Pennsylvania	Urban 8th grade students	Bodzin, 2012
Netherlands	Private homes	Brounen et al., 2013
Taiwan	Secondary students	***Lee et al., 2015***
United Kingdom	University students	Cotton et al., 2015
Denmark	General population	Sovacool y Blyth, 2015
Denmark	General population	Sovacool, 2016
Greece	High school students	Keramitsoglou, 2016
Taiwan	First year high school students	Yeh et al., 2017
Indonesia	Future physics teachers	Yusup et al., 2017
New Zealand	Children (9-10 years)	Aguirre-Bielschowsky et al., 2017
Taiwan	Vocational high school students	***Lee et al., 2017***
Indonesia	Future physics teachers	Yusup, et al., 2018
Portugal	University community	Martins et al., 2019
Taiwan	Nursing students	*Lee et al., 2019*
State of Virginia	Net-Zero building residents	Paige et al., 2019
Poland	General population	***Gołębiowska, 2020***
Portugal	University community	***Martins et al., 2020***
China	Peasant tourist houses	Zhang y Zhang, 2020
Bilbao, Spain	University community	Ortega Lasuen et al., 2020
Taiwan	Adult population	Hsu, 2020
Nepal	Urban homes	Filippini et al., 2020
Indonesia	Students and teachers of different levels	Salami, 2020
Poland	Rural community	Chodkowska-Miszczuk et al., 2021
Mashhad, Iran	General population	Sayarkhalaj y Khesal, 2022
Poland	University students	***Białynicki-Birula et al., 2022***
Vietnam	High School Students (12th grade)	*Lee et al., 2022*
South Africa	General population	Force y Longe, 2022
Brazil and Belgium	University students	*Franco et al., 2022*
State of California	Energy users	Zanocco et al., 2022
New York State	General population	Gervich, 2022
China	Ethnic residents	Wu et al., 2022
Arizona State	Future primary school teachers	Merritt et al., 2023

From the documents, it stands out that Cotton et al. (2015) suggest measures to improve energy literacy among students; while Yeh et al. (2017) identify some misconceptions that they have about energy. Paige et al. (2019) do an analysis on how energy literacy affects energy consumption in buildings that do not behave like Net-Zero, even though they were designed that way. Zhang and Zhang (2020) mention the importance of analyzing in more detail the energy literacy results obtained from questionnaires by conducting interviews. Zanocco et al. (2022) introduce the concept of "load shape" when analyzing energy literacy, considering the daily timing of electricity demand. Wu et al. (2022) explore the relationship between residents' energy literacy and sustainable tourism in ethnic areas of China.

There are two documents whose main objective is related to the evaluation of energy literacy measurements; That is, they analyze their effectiveness and applicability. Langfitt et al. (2015) analyzed the applicability of an energy literacy measure based on competency, course deliverables, or artifacts. Van der Horst et al. (2016) evaluated the pedagogical aspects of field work carried out by university students in their homes when evaluating energy technologies and habits.

3.3. Improvement tools

Of the documents analyzed, 30 have as their main objective the analysis of tools to improve energy literacy: thirteen related to their design and application, and seventeen that evaluate the effectiveness of these tools. As in the case of evaluations, in this category there are also several works that design, apply and evaluate improvement tools. It highlights that several of the tools are intended to improve the energy literacy of children or young students. Some others are intended for energy users or the general population.

For example, Huang et al. (2012) designed and implemented an energy literacy program aimed at elementary school students, and similarly, Merritt et al. (2019) developed a curriculum on energy resources aimed at fourth grade students. Jeng et al. (2013) set out to teach children concepts related to energy literacy through computer games, and Fraternali and Gonzalez (2019) describe an augmented reality tool to improve energy-saving behavior in children.

Chen et al. (2013) propose a framework for energy education that captures the concept of carbon saving and reduction in Taiwan. Tarabieh et al. (2015) designed a user-friendly data interface to simplify and support the implementation of energy literacy programs on a university campus. Wahyudi et al. (2019) sought to improve energy literacy related to geothermal energy in Indonesia, through information contained in vocational high school textbooks. Ilmi et al. (2021) designed and implemented a program to improve energy literacy in high school students; and evaluated energy literacy before and after the implementation of the program.

Regarding the general population, Moret et al. (2014) created an energy calculator within an online learning platform with the purpose of supporting citizens and decision makers to understand the energy system; Moreno et al. (2015) seek to increase energy literacy through a user-centered building management system, which provides personalized actions to save energy; Zapico and Hedin (2017) created an interactive tool to increase energy literacy; and Mogles et al. (2017) analyzed the effect of providing more detailed information in smart energy meters on energy and monetary savings. Spence et al. (2018) developed a tool with the purpose of motivating the occupants of a workspace with energy data and supporting them to take actions that reduce energy consumption.

Table 3 shows a synthesis of the documents whose main objective is to evaluate tools to improve energy literacy. This contains the type of tool, the population to which it was applied, a summary of the evaluation carried out and the reference. As can be seen in the table, the tools identified in the review include education programs (formal, aimed at students at different levels; and informal, for the general population), serious games, presentation of information, interactive activities, web pages and technologies such as smart meters and augmented reality. The populations that use the tools are mostly students, the general population, and people with some type of specific technology, such as smart meters.

 doi:10.20944/preprints202309.2079.v1

Table 3. Energy literacy assessment tools, target population, type of assessment and reference. Data until February 2023.

Tool	Population	Evaluation Summary	Reference
Formal education	High school students	Comprehensive evaluation of the impacts that an energy module had on knowledge, attitudes, behaviors, and self-efficacy.	DeWaters y Powers, (2006)
Formal education	8th grade high school students	Evaluation of the effects of two programs, one with a focus on geospatial technologies and other *Business as Usual*.	Bodzin et al., (2013)
Serious games	Serious game users	Definition of evaluation criteria of the impacts of serious games.	Wood et al., (2014)
Formal education	Secondary students	Evaluation of the hypothesis that project-based energy learning does not improve energy-related knowledge, attitudes, behavior, and beliefs.	Karpudewan et al., (2016)
Presentation of information	General population	Analysis of the interpretation of the electricity bill according to different ways of displaying the information.	Canfield et al., (2017)
Digital serious games	University students	Analysis of locus of control effects on behavioral intention and performance in game-based energy learning.	Yang et al., (2017)
Presentation of information	General population	Analysis of how people understand energy information and interpret feedback through different ways of viewing data on smart meters.	Herrmann et al., (2018)
Presentation of information	University database	Evaluating the impact of different forms of data visualization on learning about household energy consumption.	Herrmann et al., (2018)
Interactive activities	Engineering students	Evaluation of the effects of an interactive learning tool, immediate, one week and six months after using it.	Hedin and Zapico, (2018)
Smart meters	Population with energy consumption monitors	Evaluation of the effects of home energy monitors after 10 years.	Snow et al., (2020)
Augmented reality	General population	Evaluation of four augmented reality methods for representing energy consumption in air conditioners.	García-Manzano et al., (2020)
Informal education	General population	Evaluating the effects of two versions of a one-hour museum visit: collaborative or competitive.	Applebaum et al., (2021)
Formal education	Fourth grade primary school students	Analysis of the effectiveness of a service-based learning program.	Rimm-Kaufman et al., (2021)
Informal education	University students	Evaluation of the impact of an energy awareness campaign.	Ntouros et al., (2021)
Web pages	General population	Self-assessment of improvement in knowledge after interacting with two web pages: one animated and one static.	Henni et al., (2022)
Formal education	Middle and high school students	Evaluation of the effects of a workshop in the short (few days) and long term (one year) after having participated.	Keller et al., (2022)

Informal education	Building occupants	Analysis of the impact of different educational interventions on energy.	Ramallo-González et al., (2022)

Some evaluations explicitly analyze the impacts that tools have on energy-related knowledge, attitudes, and behavior, such as DeWaters and Powers (2006) and Karpudewan et al. (2016). Other documents describe the impacts of the tools in different periods of time (Hedin and Zapico (2018), Snow et al. (2020) and Keller et al., (2022)). Several of the works investigate the improvement in energy literacy using different educational programs, of which the research carried out by Bodzin et al. stands out (2013), in which a program with a focus on geospatial technologies is compared to on eBusiness as Usual; and that of Rimm-Kaufman et al. (2021), with the evaluation of the impacts of a service-based energy learning program, also against a Business as Usual scenario.

3.4. Influence

Within the group of documents reviewed, a category is proposed that includes works that investigate the influence of energy literacy on people's decision-making or behavior. This categorization was divided into two subsets: Direct influence and Model construction. The first subset includes articles whose main objective is related to analyzing how energy literacy affects other aspects of the lives of people and societies; while the second contains documents in which energy literacy is used as a variable in the construction of models designed to explain and predict phenomena related to knowledge, environment, and energy consumption.

One of the aspects in which the influence of energy literacy is most addressed in literature, of course, is energy use. For example, in the context of energy consumption of employees working in educational, health and government buildings (Medojevic et al., 2016); and in electricity consumption (Blasch et al., 2017) and excessive energy consumption (Broberg and Kažukauskas, 2021), both at the household level. It is also analyzed in the context of the barriers to the provision of solar energy systems in homes (Thomas et al., 2021) and the barriers to the implementation of renewable energies (Mehmood et al., 2022); in the context of activities that can change schedule due to the cost of energy and impacts on the environment (Walker and Hope, 2020); the Willingness to adopt temporary tariffs on energy consumption (Reis et al., 2021); and in the context of the motivations and barriers to increase flexibility in individual electricity demand (Bohdanowicz et al., 2022).

Similarly, the acceptance of energy generation technologies is analyzed (Sherren et al., 2019); preferences for efficient devices when knowing their emissions (He et al., 2022); and preferences for refrigerators according to their energy characteristics (Olsthoorn et al., 2023). Other contexts within which the influence of energy literacy is analyzed include community renewable energy projects (Cloke et al., 2017); consumer awareness viewing efficiency labels when purchasing household appliances (He et al., 2022a); and referring to the heuristics in household energy use (Van den Broek and Walker, 2019) and the heuristics of energy experts (Kantenbacher and Attari, 2021).

Regarding model construction, Mogles et al. (2018) analyze the way in which different variables relate to each other and affect energy consumption. Within the same context, Satre-Meloy (2019) applies different regularization series to regression models to analyze electricity consumption using information contained in a survey; Motz (2021) analyzes the impact that demographic, behavioral and attitudinal factors have on preferences regarding the price, origin and reliability of electricity supply; and Reis et al. (2022) analyze the behavior of a community with prosumers (a word that indicates those consumers involved in energy generation and storage activities) and vulnerable consumers. Chen et al., (20015) evaluate the interaction that exists between knowledge, attitudes, self-efficacy and behaviors related to energy; and Wang et al. (2021) analyze the dynamics of environmental regulation, including regulatory authorities, companies and civil society.

3.5. Other lines of research

In addition to the construction and application of measurement tools, the evaluation and impact of energy literacy in different sectors, there are other lines of research that are also frequently addressed in the literature. Through the review carried out, three main lines of research were found: Factors, referring to those variable elements that influence energy literacy; Education; exploring how energy-related teaching and learning is addressed in different educational programs; and Conceptual research, analyzing some concepts related to the study of energy literacy.

Regarding research related to factors, works were identified that explore the impact of practical activities among students in their final year of high school (Lin and Lu, 2018) and the field of education (Martins et al., 2019) on the level of energy literacy. Also, the effects of technological factors such as smart energy sensors are analyzed (de Leon Barido et al., 2018); the effects of geographical and contextual factors (such as socioeconomic situation, social practices and access to fuel and appliances) on children (Lusinga and de Groot, 2019); and the effects of prices and transparency in the balance of markets (Numminen et al., 2022) on energy literacy. On the other hand, the common determinants between education, financial knowledge, and energy literacy among members of a university in Portugal are studied (Martins et al., 2022)

The only work that explicitly mentions that the research was developed within the Mexican context (relevant due to the nationality and institutions of the authors) has to do with education (Castañeda-Garza and Valerio-Ureña, 2023). The document describes the review of related content with energy literacy in textbooks for primary education in Mexico. Also related to national education, Bogovic et al. (2013) present the activities developed within the framework of two competitions on energy literacy in primary and secondary schools in Slovenia; Balouktsis and Kekkeris (2013) describe the aspects of energy-related education at different levels of education in Greece; and Mažeikienė and Norkutė (2021) analyze how energy topics are presented in the geography curriculum in Lithuania.

In other works related to energy literacy in education, Cotton et al. (2016) analyze the potential risks of directing energy saving efforts solely to behavioral change and individual actions without increasing knowledge on energy issues; Van der Horst and Staddon (2018) analyze the relationship that exists between research on energy behavior and management of energy demand in the home and educational research on learning processes; Lange Salvia et al. (2020) investigate the extent to which energy sustainability is considered in educational programs and dissemination activities in 36 universities around the world; and Pestana et al. (2021) investigate the impact of some citizen energy education initiatives.

The last of the three main lines of research identified in the literature is on important concepts related to the analysis of energy literacy. Some of these works propose methodological frameworks that include different or more specific aspects than those normally included in the study of energy literacy. For example, Kavčič and Drevenšek (2014) describe a methodological framework for energy literacy that includes nuclear energy; Lowan-Trudeau and Fowler (2022) propose the concept of critical energy literacy, which considers social, environmental, political, economic, and technological aspects; and Gladwin and Ellis (2023) propose a conceptual framework on energy literacy taking into account theoretical ideas and concepts to understand energy holistically.

Also, documents that analyze energy literacy among specific groups or sectors were identified. Such is the case of the works of Aguirre-Bielschowsky et al. (2018), who investigate how 9 and 10 year old children learn about electricity and how they consume it; Adams et al. (2022) investigating the concept of energy literacy among vulnerable users, paying special attention to the specific dynamics of each place; and Plets and Kuijt (2022), which analyze the meaning and impact of private financing in the Dutch heritage and museum sectors, and assessing how it affects energy literacy.

Other works related to the conceptual research of energy literacy address the issues of analyzing the depth of energy knowledge gaps (Holasova, 2018); analysis of how to display information on the energy consumption of electrical devices in monetary terms, rather than in physical units, increases the likelihood that an individual will make a calculation and identify the device with the lowest cost throughout its life cycle (Blasch et al., 2019); promoting the sociocultural aspects of energy literacy as

 doi:10.20944/preprints202309.2079.v1

a basis for energy and climate justice (Gladwin et al., 2022); and the analysis of the contribution that energy cooperatives have when implementing and disseminating programs that promote energy literacy (Meira et al., 2022).

4. Discussion

The world is facing an energy crisis. Governments seek to ensure an energy supply that meets the demand of all sectors of the economy; while seeking to ensure that all people have access to reliable, modern, safe, and affordable energy services. At the same time, efforts are being made to mitigate anthropogenic climate change, and this requires reducing the burning of fossil fuels - oil, natural gas, and coal - which can make it difficult to achieve energy security and universal access to energy services. Furthermore, the negative effects of climate change, such as natural disasters and extreme temperatures, are adding extra pressure to global energy systems, making the current situation even more complicated.

One of the possible solutions is the energy transition (or transitions, since each country or region will have one), in which the aim is to move from an energy matrix based on fossil fuels to a low-carbon matrix with energy efficiency, renewable sources and distributed generation as pillars. That is, energy transitions must be carried out in a sustainable way and taking care of energy security and universal access to energy services. Variable renewable energies (such as solar photovoltaic and wind) require large investments for the digitalization of electricity transmission and distribution networks. However, decentralized electricity generation models can eliminate this obstacle and leverage local capabilities to create socio-technical energy systems where communities produce, manage, and generate their energy.

According to the International Renewable Energy Agency (IRENA), energy transitions around the world require 1) physical infrastructure; 2) public policy and regulatory enablers; and 3) knowledge and capabilities (IRENA, 2023). Additionally, the change in energy systems will require a well-informed and participatory citizenship, who understands the importance of transitions and can be part of the decisions when investing in infrastructure, encouraging a low-carbon matrix through public policies, and of course, being able to participate first-hand as trained human resources. It is within this context that the research field of energy literacy develop

In the scientific literature there are several definitions of energy literacy. Broadly speaking, it can be said that energy literacy is the understanding of how energy is generated, transported, stored, distributed, and used, awareness about the environmental and social impacts of its generation and use and the knowledge to use it efficiently in the different sectors of the economy. The present work seeks to contribute to the study of energy literacy by answering the research question, what are the aspects and methodologies on energy literacy that are addressed in the scientific literature? To answer it, a systematic review of the literature was carried out and the documents were grouped according to the main objective they pursue. The most relevant aspects of the articles are described in the results section.

It is important to mention that the objective of this work is to propose a qualitative classification of the articles that address the topic of energy literacy and then broadly describe the contribution they have to this field of research. However, this classification can be improved and adapted to incorporate other types of documents, for example those that address more than one main objective. According to the review carried out, the research question can be answered by saying that most of the scientific knowledge on energy literacy addresses the evaluation of energy literacy in different populations, in particular students of different levels; and the construction, application, and evaluation of tools to improve energy literacy. Other frequent topics studied are the influence of energy literacy on decision making, the factors that impact the level of energy literacy, and the conceptual study of energy literacy.

The bibliographic review carried out also allows us to grasp the importance of energy literacy in populations, so that final consumers can make efficient use of energy and they can participate in decision-making regarding energy technologies generation, transmission, and distribution of energy vectors and above all, from the authors' point of view, that people can participate in energy transitions worldwide, especially the energy transition specific to their sociocultural context. Many things are required to have just energy systems, and energy literacy is a fundamental factor in achieving them.

From the review it can be said that energy literacy is a research topic that has gained strength in recent years. Most researchers agree on its potential to promote efficient energy consumption and ensure sustainable development. For example, Lee et al. (2015) state that energy literacy can empower people to make wise decisions and take responsible actions. In the same direction, Gołębiowska (2020) mentions that increasing energy literacy can be key to ensuring sustainable development in the coming years. Martins and collaborators (2020) expect that basic knowledge about energy and financial knowledge will serve to provide citizens with the tools and motivation to make the necessary changes and achieve efficient consumption habits.

However, the same authors mention that most studies show that even in populations that have adequate knowledge about energy, this knowledge does not transform into a strong motivation leading to behavioral changes (Martins et al., 2020). And although in most of the documents reviewed there is consensus on the importance of energy literacy, the disagreements are whether energy literacy translates into efficient energy consumption. In this regard, Adams et al. (2022) mention that several researchers have found that the data suggests that there is no correlation between an increase in energy literacy and an increase in sustainability. Which coincides with the statement of Van den Broek (2019), who says that the literature shows little evidence on the impact of energy literacy on energy consumption habits.

Although the way energy is used may not be strongly related to the level of knowledge, an informed and energy literate citizen is more likely to participate in decision-making processes and will be better prepared to choose and act responsibly on energy issues. (DeWaters and Powers, 2013). The authors of this document consider that regardless of whether the increase in knowledge about energy makes an impact on actions aimed at having efficient energy consumption, energy literacy is essential for people who do seek to improve their energy use habits and contribute to sustainable development, can do it effectively. And, most likely, knowing the environmental and social impacts of the generation, transportation and use of energy can encourage people to seek to change their consumption habits.

As for future work, it is important that spaces be built to improve energy literacy, especially in Latin America, both with formal education programs at different educational levels, and with non-formal education projects to be able to access the majority of the population. Also, it is necessary to build tools for the evaluation of energy literacy in people and knowing which the main issues are to improve. Another important research opportunity is found in the correlation between energy literacy and the efficient use of energy, particularly on the mechanisms that can improve this relationship and ensure that people with advanced knowledge about energy are precisely those who consume it efficiently.

It is essential that governments and the private sector, particularly energy companies, get involved in improving the level of energy literacy of civil society; however, academia must be the protagonist in this sense. Scientists working on energy issues must actively participate in having citizens with a high level of energy literacy, capable of participating in an informed manner in decisions related to energy and having sustainable energy consumption, both individually as well as collectively.

Author Contributions: Conceptualization, O.S.S.; methodology, O.S.S. and K.G.C.; software, K.G.C.; validation, O.S.S and K.G.C.; formal analysis, O.S.S; investigation, O.S.S. and K.G.C.; resources, O.S.S. and K.G.C.; data curation, O.S.S.; writing—original draft preparation, O.S.S; writing—review and editing, O.S.S. and K.G.C.; visualization, O.S.S.; supervision, O.S.S. and K.G.C.; project administration, O.S.S..; funding acquisition, NA. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The author O.S.S. thanks the Mexican National Council of Humanities, Sciences and Technologies (CONAHCyT) for the postdoctoral grant with the application number 4198764 provided for the completion of this work.

Conflicts of Interest: The authors declare no conflict of interest.

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