

CONCEPTIONS AND PERCEPTIONS ABOUT SOURCES OF ENERGY AND RELATED TECHNOLOGIES

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Abstract

Nowadays, there is a growing demand for electric energy, which is needed to foster economic development as well as to sustain modern lifestyles (e.g., for transportation, and communication services). For many years, fossil fuels were the main energy source for electricity generation. Yet, since the 1990s, there has been an increasing trend to use renewable and clean energy sources for energy generation. This paradigm shift arises not only from the scarcity of fossil energy resources, but also from the need to mitigate the increase in global warming so that the Earth's balance is not compromised. As governments search for transitions to low-carbon energy systems, by fostering the use of a variety of renewable sources of energy, energy literacy, particularly among ordinary citizens (students included), remains low and needs to be promoted. Promoting it successfully requires an understanding of citizens' conceptions and perceptions about energy, energy sources, and their related technologies, as they may interfere, either facilitating or hindering, with the implementation of energy transition projects, as well as with school learning. This paper, within the scope of the GREENLIGHT Erasmus+ project (ref. 2023-2-TR01-KA220-SCH-000180691), aims to present a literature-based synthesis on citizens' conceptions and perceptions about energy, energy sources, and their related technologies. The literature reviewed reveals that energy is conceptualized as something material or a force; renewable energy sources are perceived as cost-free, insufficient to meet energy demands, unable to replace fossil fuels; and environmentally friendly and pollution-free. Citizens generally hold positive attitudes towards renewable energy sources, as long as large-scale energy plants are not built. Thus, the literature highlights the need for improving energy literacy education, so that it can contribute to overcoming citizens' alternative conceptions and negative perceptions about sources of energy and related technologies.

Keywords: conceptions of energy, citizens' literacy, sources of energy, energy literacy, perceptions of renewable energy sources.

Introduction

Human reliance on energy for everyday life is undeniable, as all daily activities require its use. This energy dependence continues to increase due to rapid population growth, widespread urbanization, and rising of living standards, all of which amplify the impact of energy consumption (GREENLIGHT, 2024). In our energy-dependent societies, it is crucial that citizens hold accurate understanding of energy and energy-related technologies, and become informed about the benefits, limitations, and implications of (non)renewable energy sources.

Understanding energy is challenging for students and the general public (Eisenkraft et al., 2014, Lancor, 2012). As Feynman's (1963) stated: energy is a "numerical quantity which does not change when something happens. It is not a description of a mechanism, or anything concrete" (p. 4-1). Thus, energy is not directly observable, and cannot be measured directly, but it flows into and out of physical systems, leading to measurable changes. Demirel (2012) and Falk, Herrmann, and Schmid (1983) use the term 'energy form', such as chemical, electrical, light, mechanical, or nuclear energy, to describe how energy changes within and between systems.

Concerning its origin, energy can be classified into primary energy and secondary energy (Demirel, 2012). Primary energy refers to energy extracted or captured directly from the environment, and includes both non-renewable and renewable energy sources. Non-renewable energy sources come from fossil fuels (coal, crude oil, natural gas) and nuclear fuel, while renewable energy sources include hydropower, biomass, solar, wind, geothermal, and ocean energy (Demirel, 2012). Secondary energy results from the conversion of primary energy sources into more usable sources, such as fuels like gasoline, fuel oil, methanol, ethanol, and hydrogen (Demirel, 2012). Although both renewable and non-renewable energy sources are available, data on global energy use shows that the majority of energy used comes from fossil fuels (GREENLIGHT, 2024). This reliance on fossil fuels has led to several problems, namely energy dependence on countries lacking fossil fuel resources; the depletion of reserves, which take millions of years to regenerate; and environmental damage, as a result of the emission of greenhouse gases into the atmosphere. These emissions contribute significantly to global warming (GREENLIGHT, 2024). These problems have led to rethink the energy sources that have been used and led to a growing demand for renewable energy sources, which are environmentally friendly and sustainable (GREENLIGHT, 2024).

Renewable energy sources have become central to the ongoing energy transition, a process that also requires the continuous development and implementation of innovative technologies. Yet,

this process of energy transition is not straightforward. Citizens' choices between non-renewable or renewable energy sources is not consensual, and often stem from a lack of understanding regarding the advantages and disadvantages of different energy sources, the technologies involved in their use, and, in some cases, from persistent misconceptions. These perceptions and misconceptions need to be clarified and overcome through initiatives to promote energy literacy, carried out in both formal and informal school contexts. Only by doing so can citizens be equipped with the necessary knowledge to make informed decisions on the use of various energy sources and to critically assess their environmental benefits or drawbacks.

This paper, developed as part of the project Generating Renewable Energy Education Network – Leading Initiatives for Green & Harmonious Tomorrows (GREENLIGHT), presents a literature-based synthesis on citizens' conceptions and perceptions about energy, energy sources, and their related technologies and is organized in two main sections: 'Misconceptions about energy held by students and adult citizens', and 'Public perceptions of (non-)renewable energy sources and energy-related technologies.

Misconceptions about energy held by children and adult citizens

The science use of the word energy differs from everyday use, where it often seen as a material that can be bought, is expensive and needs to be saved (e.g. fuels) (Ross, 1993, Tatar & Oktay, 2007). It is also considered part of food, so it can give energy to people when they need it (Ross, 1993). It is also often erroneously mixed with the concept of force. Everyday experiences often lead to misconceptions, which tend to persist over time regardless of students' grade level (Ross, 1993). According to Trumper and Gorsky (1993), those misconceptions can be grouped in eight broad categories, which are presented on Figure 1.

Energy conservation is another important theme, which research shows that students and even teachers often struggle to understand it (Riggs 2023). By the end of secondary school, few students can apply the principle of energy conservation effectively or answer questions on energy conservation accurately. Understanding energy conservation poses some challenges because it requires a high level of integration of energy ideas.

Figure 1

The eight categories that group students' misconceptions

- Energy is associated with people.
- Things possess and expend energy.
- Energy causes things to happen.
- Energy is an ingredient in things and can be released by a trigger.
- Energy is associated with activity.
- Energy is created by certain processes.
- Energy is a generalized kind of fuel associated with making life comfortable.
- Energy is a kind of fluid that is transferred in some processes.

Additionally, students' misunderstandings on energy conservation are diverse (Figure 2), and are often reinforced during teaching (Solbes, Guisasola, & Tarín, 2009).

Figure 2

Misunderstandings about energy conservation

- Energy is used up or lost.
- If it stays in the system, energy will be conserved.
- Energy degradation means a decrease in its quantity.
- Energy degradation is the opposite of energy conservation.
- Energy conservation means saving energy.
- Energy is stored in food and fuel.
- If the environment is a part of the system, energy is conserved; if it is not, it is degraded and dispersed.
- Energy 'conservation' and 'energy degradation' are opposite facts to each other.

Students' misconceptions about energy and its conservation are often reinforced or induced by traditional teaching approaches. These include: defining energy as a system's capacity to do work, that is using a circular definition since it is impossible to define one concept without the use of the other; describing energy as "what makes things go", which wrongly implies that energy acts as a causal agent (Randor, 2012); or presenting, at lower school levels, energy as "forms of energy" that can be converted into another one, without clearly explaining what these

various energy forms are (Falk, Herrmann, & Schmid, 1983). This last approach can lead to misconceptions (e.g. that 'chemical energy' is a substance stored inside molecules) (Cooper & Klymkowsky, 2013). The use of multiple and sometimes unclear definitions of energy throughout school years, makes it difficult for students to develop a scientific understanding of the concept, and to use it to think about phenomena (Driver & Warrington, 1985, Jin & Anderson, 2012, Trumper, 1993).

Public perceptions of (non-)renewable energy sources and energy-related technologies

Citizens from different countries hold different perceptions on renewable and non-renewable energy sources and on energy-related technologies, which will be presented in turn. *Fossil fuel* acceptance is shaped by economic interests and efforts to protect them; in countries with significant fossil fuel extraction, citizens are less likely to believe that increasing of global warming is caused by human activities (Knight, 2018). A similar trend occurs in countries that do not produce fossil fuels, but rely on them to meet energy needs. Emotional attachment to technologies, that traditionally use fossil fuels, also influences perceptions of environmental risk (Knight, 2018). For example, in driving technology, Rößler et al. (2024) found that drivers with affinity for cars tend to perceive lower risk in e-fuels and fossil fuels, while showing greater concern about electric vehicles. This contrasts with the general public, which are more favourable to e-fuels and electric engines vehicles.

Studies on public attitudes towards renewable energy sources generally report positive views. Yet strong opposition to energy-related technologies remains (Botelho et al., 2016, Krohn & Damborg, 1999, Wolsink, 2000). In between, some citizens support renewable energy-related technologies as long as they are not located in their immediate vicinity, a phenomenon often referred to as 'not-in-my-backyard' (van der Horst, 2007). This reflects a degree of selfishness, limited understanding of the need for renewable energy sources, and negative emotional reactions (Batel, 2020). Public acceptance of renewable energy-related technology depends on minimal local impact (Sütterlin & Siegrist, 2017). Misconceptions regarding renewable energy include: renewable energy is free, is insufficient to meet energy needs, does not reduce fossil fuel use, is entirely environmentally friendly and free from pollution (Cheong et al., 2014).

Studies on public perceptions of different forms of energy-related technology and their impacts have provided a mixed set of findings, as shown in the following reviews (Table 1). *Solar*

energy is one of the most well-known energy sources to the public (Khambalkar, 2010), and is often preferred over other renewable energy sources (Sütterlin & Siegrist, 2017, Jobin & Siegrist, 2018). Yet, when solar technology is developed on a large scale, public acceptance declines and several misconceptions are held by secondary students (Cousse, 2021). They believe that solar cells are the only technological equipment needed to heat water, or that solar photovoltaics will only work when there is direct sunlight (Cheong et al., 2014).

Table 1

Public perceptions and misunderstanding of renewable energy sources

Category	Positive aspects	Negative aspects
<i>Solar energy</i>	It is often preferred over other renewable energy sources It is the preference source for achieving climate-neutral	Its acceptance declines as large-scale infrastructures are built Misconceptions - solar cells are enough to heat water - solar photovoltaics only work in direct sunlight
<i>Wind energy</i>	It is well-accepted due to: economic benefits for local communities; conservation of natural resources	Misconceptions - wind turbines: produce extremely noise, cause significant bird deaths
<i>Geothermal energy</i>	It is seen as a driver of job creation	Technologies may: induce seismic activity, cause groundwater contamination, noise and air pollution
<i>Hydropower energy</i>	It is seen as a driver of job creation, stable and a source of low-cost electricity Enhances energy security	Hydropower plants cause: disruptions to natural habitats; threatens cultural heritage, affects drinking water quality; generates noise. Misconception: hydroelectric power only works with large dams.
<i>Biomass energy</i>	Positive view when using 'forest or industrial residues	Limited acceptance due to a lack of understanding of how biomass energy is generated

		Concerns about using crops or farmland for producing energy
<i>Wave energy</i>	It often receives positive or neutral attitudes	Negative opinions are limited because wave energy is relatively unknown

Wind energy is well accepted by citizens. However successful implementation in local communities depends on whether an onshore wind farm is perceived as fair in its impacts on residents and in the processes used to achieve those outcomes (Walker & Devine-Wright, 2008). Attitudes towards offshore wind energy are not consensual and appear to be shaped by cultural identity. Favourable views on wind energy depend on economic benefits for local communities, and unfavourable views depend on visual impact, concerns about ecosystem disruption, and noise pollution (Bidwell, 2013, Rogers et al., 2008). Misconceptions related to wind farms include: wind turbines produce excessive noise audible from several kilometres away; and blades kill birds (Cheong et al., 2014). In addition, there is a lack of familiarity with the structure and mechanisms of the wind turbines (Marinho, 2009).

Geothermal energy causes concern to the public who believe that: seismicity is induced by energy generation technologies; there will be potential groundwater pollution, resulting from geothermal technology installation and operation; it will cause noise and air pollution. Nevertheless, geothermal projects are often viewed as opportunities for job creation. Public opinion on this energy form is strongly influenced by direct experiences with geothermal energy and familiarity with its related technologies (Renoth et al, 2023).

Hydropower energy acceptance is influenced by several factors, namely 'economic, and environmental costs and benefits' (Venus et al., 2022). Benefits include job creation, stable and low-cost electricity and energy security. On the other hand, the associated costs involve disruptions to natural habitats, threats to the cultural heritage of a region; concerns about drinking water quality, and noise generated from hydropower plants. In countries with a long history of hydropower, the technology has generally been accepted as important to the economy due to its contributions to industrial development. There is, nevertheless, the idea that hydropower energy only works if large volumes of water are stored behind a tall dam, disregarding situations such as run-of-the-river hydroelectric systems (Cheong, 2014, Venus et al., 2022).

Public perceptions of *biomass energy* and *wave energy* receive less attention in research. Attitudes towards biomass energy depend on the type of biomass feedstock, with concern about

using crops or farmland for biomass energy. Limited public understanding of how biomass works affects its acceptance (van Dijk, Goedegebure & Nap, 2024).

Wave energy technology is still largely in the development phase; the existing studies point out that citizens express positive or neutral attitudes toward wave energy, and hold little knowledge about it (Stelmach et al, 2023).

Discussion

The transition to renewable and clean energies has become not only an increasing concern but also a pressing demand for action. While governmental measures play a key role in the energy transition, it is important to recognize that all citizens also have a part to play. However, citizens need to have energy literacy for effective engagement because it provides them with scientific knowledge about energy and energy-related technologies, which enable them to make informed energy decisions in their everyday life. This synthesis based on a literature review identified misconceptions and attitudes towards energy and energy-related technologies, which may hinder the development of energy literacy. Thus, actions are needed to address misconceptions and negative attitudes towards energy. Students and teachers are crucial in this process, which is why they are the main focus of GREENLIGHT project.

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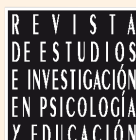
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