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Energy Literacy in Portugal: A System Map and Framework to Increase Energy Literacy Through the Renewable Energy Transition

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Abstract

Western society lives with a great dependence and an almost simultaneous ignorance of energy consumption (van den Broek, 2019). The systemic landscape of energy knowledge and dissemination is more critical than ever as Portugal races to meet decarbonization goals. This paper fills a knowledge gap by updating the current social landscape of energy literacy in Portugal through a comprehensive system map and framework to increase energy literacy levels through the renewable energy transition. By conducting a semi-systematic literature review, meta-narratives and themes were identified and used to create theoretical concepts, a framework, and a system map. This research found that energy literacy is a factor of governmental regulations, the education system, information shared by energy companies, and geographical location. Increasing energy literacy through the renewable energy transition is possible through implementing national energy educational programs, a national strategy for energy research, and regulating the data analytics shared to consumers by energy companies. Future research is required to gain nationwide data on energy literacy and investigate the relationship among renewable energy dissemination, energy literacy, and attitudes towards decarbonization goals.

Keywords

Energy literacy, energy invisibility, renewable energy transition, sustainability, systems theory, system mapping, social change, Portugal

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1. Introduction

Western society lives with an almost complete dependence and simultaneous ignorance of energy, both in direct and indirect consumption (van den Broek, 2019). The phenomenon is called energy invisibility. The parallel between a growing global population and income levels continues to pressure energy demands, and this demand is only predicted to increase in future years (International Energy Agency, 2019). Furthermore, society is currently confronted with making momentous, consequential decisions in the face of the changing climate (Ambrose & Sheffield, 2020). The systemic landscape of energy knowledge, production, and dissemination across society is more critical now than ever. An essential good, energy requires thoughtful consumption and management, and this starts with energy literacy (Martins et al., 2020a).

Clean energy adaptation and reducing demand is a global effort required to mitigate the impacts of climate change across the globe (Cotton et al., 2021). Despite energy sector goals, the implementation of renewable energy technologies flounders its potential, partially due to economic market failures and system inertia (Irena, 2016). The way people relate to, understand, and interact with energy consumption will continue to influence whether climate goals are met. Renewable energy resources are increasingly penetrating the electricity generation sector which aids in the decarbonization of the global economy. However, if the population does not understand what electricity is, then how is a change in motivation and dedication towards changing energy behaviors possible? The public relies heavily upon energy and electricity, yet many people are not able to answer simple questions of how it works, where their energy supply comes from, and the consequences of their energy consumption behaviors. This modern-day detachment to the production and consumption patterns of energy has bred a variety of issues, including a growing distrust with energy companies (Ambrose & Sheffield, 2020).

A study conducted by Reis et al. (2021), found that in Portugal, there was a trend of overconfidence in an energy self-awareness test across university students. On this energy literacy assessment, there was a consensus that students' actual knowledge on energy was substantially lower than their self-assessed knowledge (Reis et al., 2021). A survey conducted by SaveOnEnergy in 2020 revealed that only 12% of UK millennials knew how to calculate where they can save on their energy bills, which is one piece of data showing the rather low levels of energy literacy (SaveOnEnergy, 2020). Also, it has been found that people do not purchase the most energy or cost-efficient appliances or make efforts to save energy efficiently in their households (Lindén et al., 2006). This illiteracy is present across Europe and the world.

With as many challenges society is facing, the renewable energy transition can be viewed as an opportunity for widespread societal changes and paradigmatic shifts in the way people relate to energy resources. Naturally, energy transitions are interlaced with political and social issues. Social science research on energy relates to the interaction among social institutions, the political economy, and energy governance (Becker & Naumann, 2017). Energy literacy, as a product of the interactions among social institutions, is essential to making informed decisions about the use,

production, consumption, and management of energy resources. Knowledge alone about energy is not equivalent to literacy. Instead, literacy refers to the ability to translate knowledge into actions (Martins et al., 2020a). This type of literacy is key for communities, cities, and countries meeting their climate goals and for individuals to be more empowered and connected to a sense of place. Energy literacy houses the potential for important predictions and shifts in energy-related behaviors (Cotton et al., 2021).

According to van den Broek (2019), there are four forms of household energy literacy including device energy literacy, action energy literacy, financial energy literacy, and multifaceted energy literacy. DeWaters and Powers (2013) identified three main attributes to energy literacy as a whole, which are cognitive, effective, and behavioral. These authors created measurable benchmarks to measure these aspects and stress the importance of ensuring that these criteria remain relevant with respect to current energy topics (DeWaters & Powers, 2013). Since this paper was published almost a decade ago, there are grounds for this information to be considerably updated. There is a need to improve the quality and impact of research on energy literacy in order to aid in better recommendations for policy makers to facilitate domestic energy conservation (van den Broek, 2019).

The knowledge gap that this paper attempts to fill is creating an updated summary and model to display the current social landscape and state of energy literacy in Portugal and combining literature into a cohesive framework on increasing energy literacy. This paper fills this gap by offering the following: (1) creating a comprehensive system map of energy literacy in Portugal; and (2) developing a new framework to increase energy literacy levels specifically through the renewable energy transition in Portugal. To propose ways to increase energy literacy in the renewable energy transition, there first needs to be a foundational understanding of the systematic landscape of why energy literacy remains low across Portugal. This research will explore how issues of justice, community engagement, and empowerment are related to the topic of energy literacy.

First, this paper covers a foundational background of terms and concepts, provides definitions, and presents relevant social theories applied in this research. Then, this paper discusses background information, such as the current state of the energy transition in Portugal and current research articles that served as the guiding forces in creating the new framework through a literature review. Subsequently, this paper discusses the methods used and displays the results of a system map and new framework, combined with a discussion of why these findings are relevant to this emerging field. Finally, this paper concludes with a summary of research and offers future research recommendations.

1.1 Research Objectives

This paper will explore energy invisibility by attempting to answer the following questions: (1) How is energy literacy situated in the systemic landscape of social institutions?; (2) How can energy literacy be sustainably increased in Portugal, particularly through the renewable energy

transition? This paper answers this question by creating a comprehensive system map of the factors that influence energy literacy levels of individuals and corporations, as well as developing a new framework to increase energy literacy levels specifically through the renewable energy transition in Portugal. This paper seeks to address the struggle of increasing energy literacy levels across Portugal, and the resulting social issues of the lack of sense of place and nescient energy consumption behaviors.

2. Theoretical Information

Important terms and concepts will be used throughout this paper which merit specification and definition. These definitions are far from complete, however this table provides a decent foundation for understanding their uses in this paper. Below are two tables, one of common terms and concepts, and one of key sociological theories that were implemented through the research and analysis process.

2.1 Terms and Concepts

The following table presents concepts central to the literature review and background information sections. These terms are prevalent throughout the results and discussion as well.

Energy	Energy can be understood as the ability of a system to do work. It is a quantity that is transferred from system to system. The ability to do work refers to a system exerting force on another system. Energy is measured and tracked in many different units and during transfers into or out of a system (U.S. Department of Energy, 2012).
Energy Literacy	DeWaters and Powers (2013) define energy literacy as the combination of basic energy-related knowledge and an awareness of the impacts of energy production and consumption, as well as an understanding of how energy is used in daily life and how to adopt energy saving behaviors. Energy literacy is seen as a tool that sensitizes citizens towards sustainable energy consumption behaviors. (Martins et al., 2020a). The U.S. Department of Energy (2012) defines energy literacy as encompassing the ability to apply an understanding of energy towards answering questions and solving problems.
Renewable Energy Transition	The renewable energy transition describes the global energy sector's shift away from fossil-based systems of energy production (such as oil, coal, and natural gas), and towards the production and consumption of renewable energy sources (such as solar, wind, and geothermal). The key drivers of the energy transition are electrification and an improvement in energy storage (such as batteries) (S&P Global, 2020).

Energy Poverty	Energy poverty refers to the combination of low income, high expenditure of disposable income on energy, and living in buildings with poor energy efficiency. These factors can lead to inadequate air quality, exposure to harmful materials, health problems, and higher mortality and negative mental health rates (European Commission, 2021). Women are at higher risk of energy poverty than men, and approaching energy poverty studies with a gender-aware approach is necessary for sustainable justice (Mikkonen et al., 2020).
Systems-Based Approach	System-based approach utilizes the understanding of systems as interactive and interdependent in relation to processes and phenomena, with special attention to cause-and-effect connections within and among systems (U.S. Department of Energy, 2012).
Sustainability	The ability of a behavior or practice to be maintained at a consistent level without exhausting natural resources or causing intense ecological damage (U.S. Department of Energy, 2012).
Sustainable Development	Social systems' ability to meet the needs of the present without compromising the ability of future generations to meet their own needs, with a larger objective to interact with ecosystems in a way that permits them to maintain their functional integrity (Marten, 2008).

2.2 Sociological Theories

The following concepts are theories of thought or heuristics in which to view the world. The following theories stem from the sociological perspective which relies on the notion that human behavior is greatly shaped through social interactions, institutions, and relationships. These theories bring context to individual circumstances and provide explanations for social problems, such as energy illiteracy.

Structural functionalism	Structural functionalism is one of the three main theories used in sociology to understand the organization and functioning of society. Founded by Émile Durkheim, this theory interprets society as an interdependent collection of social institutions. The interrelations between the parts of society can produce "organic solidarity", which exists on the assumption that society is composed of differentiated and specialized functions, such as institutions like education, the government, and the military. In this theory, social change is viewed as an adaptive response to tension within the social system (Duignan, 2020). The integratedness of social institutions creates a natural regulation of individual and social life. The way social structures are built of different

	indispensable functions provides an understanding of why social change is usually met with great tension and can occur slowly as different institutions take time to adapt (Duignan, 2020).
Systems theory	Systems theory is a lens in which to understand the institutionalization of social problems in society. Systems theory views society as composed of different inputs, outputs, flows, and stocks that together create functional or dysfunctional parts of the whole. Systems theory exposes the complexity of social evolution, adaptive possibilities, and leverage points for social change in the composition of social institutions. Donella Meadows, Talcott Parsons, Robert Merton, and others have adopted the systems theory approach in their work, which can be interpreted as closely related to structural-functional analysis and the scientific study of social organization (Gibson, 2019).
Environmental Justice	An interdisciplinary field of study that recognizes that environmental burdens fall unevenly across social groups and geographical locations. Recognizes that poor and marginalized communities are more likely to suffer negative consequences of energy decisions, due to the lack of negotiating power and lower resources for adaptive capacities (CLEAN, 2021).
Critical Environmental Justice	Critical environmental justice, traced to David Pellow, adopts a special focus on the presence of intersectional systems of oppression and attention to spatial and temporal scales of problems and solutions. Critical environmental justice examines the role of state power in reproducing and reinforcing embedded social inequities, as well as an emphasis on the indispensability of populations that are often viewed expendable (Amiri, 2020).

3. Background

3.1 Acknowledging the State of Sustainability and Energy in Portugal

According to IEA's 2021 Energy Report, Portugal exhibits a strong focus on expanding electrification, renewable electricity generation, and energy efficiency measures to meet goals of carbon neutrality. Portugal has been a member of the International Energy Agency since 1981 (International Energy Agency, 2022). Portugal was one of the first countries to establish 2050 carbon neutrality goals shown through the Roadmap for Carbon Neutrality 2050 (RNC2050), which calls for renewable energy production to cover 88% of the final energy demand and major demand reductions through pursuing energy efficiency solutions. Portugal's long term carbon neutrality goals also rely on hydrogen technologies.

However, Portugal's energy mix is still dominated by fossil fuels. In 2019, Portugal's primary energy supply was composed of 76% fossil fuels, of which all oil, natural gas, and coal

were imported, and these activities have increased Portugal's greenhouse gas emissions. The wildfire of 2017 facilitated increasing greenhouse gas emissions, and this risk of extreme wildfires still faces the country. On the brighter side, in 2021, Portugal's last two coal-fired power plants permanently closed (International Energy Agency, 2022). Portugal's energy production in TJ has increased 79.94% from 1990 to 2020. There is a trend of nonrenewable energy supplies declining over from 1990 to 2020 as supplies, infrastructure, and policies supporting renewable energy sources increase (International Energy Agency, 2022).

Additionally, Portugal has established efforts to reduce energy import dependency. On the topic of energy dependence and security, Russia's recent invasion on Ukraine has agitated geopolitics and the energy market. With oil and gas prices at their highest prices today in over a decade, European countries are forced to reexamine their energy supplies and the liability of dependence on Russia. Russia supplies about 40% of the natural gas supply of the European Union and is the world's largest oil exporter (Tollefson, 2022). However, Portugal and Spain form an "energy island" which has emerged as strategically advantageous due to their low reliance on Russian natural gas (Associated Press, 2022). European Union leaders are escalating the shift to renewable energies in the face of this crisis.

From 2016 to 2020, Portugal showed recovery from the economic depression of the 2008 financial crisis, even with notable impacts from the Covid-19 pandemic. Portugal received 13.9 billion from the EU, with a portion of EUR 610 million for energy efficiency and renewable energy in buildings and EUR 185 million for the production of renewable gasses like hydrogen and biomethane. Portugal is now taking steps to speed up permitting and grid connections of solar photovoltaic projects, as well as financing programs for energy efficiency. Portugal has achieved high levels of electriciation and high shares of renewable energy. In 2019, electricity covered a quarter of Portugal's total final energy demand at 25%, 54% of which was generated by hydropower and wind. Building, industry, and transport sectors have an immense amount of work to do to lower energy demand, reduce emissions, and increase renewable energy. The EU Emission Trading System (ETS) encourages greenhouse gas emission reductions, however research has shown this system to have controversial effects (da Silva et al., 2021). Although there has been limited growth in renewable energy over the past few years, Portugal has tasked with rapidly expanding this sector in a race to meet 2030 targets (International Energy Agency, 2022).

Portugal also made affordable access to energy a priority on their roadmap. Portugal's energy poverty rate in 2018 was recorded at just under 20% of the population, which is considerably higher than the EU average of 7.3%. Portugal is developing a national strategy to combat energy poverty through addressing issues that contribute to poverty in the first place, including institutional renovations that reduce consumer bills, energy demand, and practices that can improve the comfort and security of residents. Lastly, the Azores and Madeira are regions of Portugal that autonomously set their own energy strategies, goals, and policies. Although these islands still rely heavily on oil, they have more ambitious climate goals than mainland Portugal and can be testing sites for new programs that support the energy transition (International Energy Agency, 2022).

3.2 Current Research

In a 2019 research study, Karlijn van den Broek examined household energy literacy through critically reviewing extant literature and research. One facet of the typologies, financial energy literacy, can be understood as the awareness of energy bill costs, energy prices, and conduct investment analysis of energy saving investments against future energy costs. In van den Broek's research, almost half of householders did not understand the costs of their energy bills, which suggests low financial energy literacy. These findings emphasize the need for more research on energy literacy in order to aid policy makers in developing effective energy conservation regulations at the household level.

Similar to the goals of this paper, Martins et al. (2020b) compiled existent research to assess the literacy levels of the population, explored the relationships between them, and determined which factors may influence them. In this research, authors propose a more comprehensive assessment of energy and financial literacy levels to be used by future researchers or current policy makers. In another study, the same authors explore the knowledge, affect, and behavior related to energy literacy of university members in Portugal (Martins et al., 2020a). This study emphasizes the importance of the "knowledge" indicator of energy literacy, especially when crafting future programs and policies to promote energy literacy, although attitudes and behavior indicators can be improved as well.

In terms of the educational aspects of increasing energy literacy, Aguirre-Beilschowsky et al. (2017) explored the role of energy education on environmental citizenship in New Zealand children (age 9-10). In 2013, Jan DeWaters and Susan Powers created a framework to measure energy literacy to improve secondary students' general energy literacy. In their research project, DeWaters and Powers present data on American energy literacy levels, which tend to be low, as well as the beginning of people becoming more aware of renewable energy resources (DeWaters & Powers, 2013). In the same vein, DeWaters et al. (2007) developed an energy literacy scale for middle and high school students, which provides my research with a foundation of the relationship between energy literacy, environmental literacy, and technological literacy. These authors offer a resource of information on defining and conceptualizing efforts to measure and promote energy literacy.

Additionally, research by Cotton et al. (2016) found through survey and focus groups that their 4E's model of enable, engage, exemplify, and encourage had positive impacts in improving knowledge, attitudes, and behaviors of university students' energy literacy levels in the UK. Brounen et al. (2013) conducted primary research through surveys to quantify relationships between energy literacy, awareness, and household conservation efforts. This research provides more foundational understanding regarding the main assumptions underlying most energy efficiency policies, as well as the power of behavioral "nudges" in affecting residential energy consumption.

To better understand how to reconnect people back to energy and promote environmental citizenship, Ambrose and Sheffield (2020) used participatory research to create the Walking with Energy framework. This framework is a combination of social, locally embedded, and embodied approach that shows, through a pilot study in the UK, this framework's effectiveness at prompting a reconnection between participants and energy. This research exemplifies the successes of designing an immersive experience for participants that has the potential to create lasting changes in attitudes and behaviors towards energy consumption and literacy. The goal of their study remains highly relevant in society today as the globe faces the responsibility to address the gap and help citizens reconnect with energy, raise awareness of the consequences of energy consumption, promote environmental citizenship in the face of climate change, and engage citizens in debates surrounding energy policies (Ambrose & Sheffield, 2020).

Lastly, Chodkowska-Miszczuk et al. (2021) analyzed energy literacy in rural areas and the relationship between literacy and resilience. Their findings suggest that educational reinforcement within the community and more developed long-term institutional support from the central government are essential in the viability of rural energy transitions. These authors also explored the impacts of socio-economic factors on energy conservation behavior and the utilization of renewable energy resources, using both macro (European level) and micro (local level) scale research perspectives (Chodkowska-Miszczuk et al., 2021). These authors take into account energy poverty levels. Community resilience, whether urban or rural, is important in the current social dialogue on climate change adaptation and mitigations, as well as the energy transition. As much as there is literature on energy literacy, more research is critically needed to address the sizable climate and social pressures at hand.

4. Methods

Through doing in depth research on extant literature, the purpose of this project is to identify leverage points through the system map that can be used to increase literacy levels and guide future responsible energy consumption behaviors. The methods of this research include a semi-systematic review of extant literature to synthesize and unite differently conceptualized studies of energy literacy from various authors and researchers. The literature review relies on a multi-sectoral approach by selecting literature from a diverse range of disciplines. This review seeks to identify and understand a multifaceted view of the factors that influence energy literacy through researching all potentially relevant research topics and traditions. By conducting a literature review through this multi-scalar lens, meta-narratives were identified across literature and themes were detected that were essential in creating theoretical concepts, framework, and system map.

This research began with conducting a broad search of literature on energy literacy with methodology enhanced by recommendations from Snyder (2019), specific data and research conducted in Portugal, and understanding terms better across digital databases and peer-reviewed articles. Additionally, Thinking in Systems (2008) by Donella Meadows was read, which emerged

as a foundational text used in preparation of creating the system map for this research project. Meadows' text provided the language and imagery to understand the interrelationships among social and natural systems. This text elucidates key system features, such as sources of system stability and system growth and change, as well as system surprises, traps, and leverage points. Through these readings, previous sociological training at CU Boulder, and School for International Training lectures, this research was conducted with a cultivated "systems thinking" mindset through which to see the intersections of society and environment, social systems, and natural systems.

4.1 Theoretical Assumptions

This analysis holds the assumption that energy consumers are rational actors, as understood by rational choice theory. The analysis also believes that people operate through a lens of bounded rationality and make choices based on relatively limited amounts of information, as relayed by Herbert Simon.

4.2 Limitations

The system map and framework were created through Google Draw software. It was difficult to find a better software to use for this purpose, so there are limitations within the design of these items inherent to the Google Draw functions. Another obstacle that arose in this research includes the time limitation of having only four weeks to complete this research project from start to finish. The research would have been supplemented by pursuing primary research methods to fill research gaps in energy literacy in Portugal, and specifically in Lisbon, however this was not possible with the time constraint. The quality, depth, and scope of my data is limited by the time constraint given for this project.

4.3 Ethics

This research used solely secondary data sources to organize and validate the hypothesis, therefore, no primary data was collected. Since primary data was not collected, the research did not involve any human participants. This project assumes full responsibility for treating the work of existing researchers accurately and fairly in the analysis through the use of thorough citations and references, as well as addressing ethical questions that arise through the research process.

5. Results and Discussion

5.1 System Map of Energy Literacy in Portugal

When approaching the landscape of energy literacy in Portugal, it is important to first recognize what structural factors lead to the existence of energy literacy. Energy literacy is a product of a large-scale socio-ecological system (van den Broek, 2019). Figure 1 displays energy literacy as the product of the main social systems of education, governmental regulation, energy providers, and geographical situation of individuals. The solutions for transforming society towards sustainable development goals lies within understanding this system. It is essential to frame energy literacy within a societal context. Energy related behaviors are limited by certain factors in the social landscape, such as financial, geographic, and social settings (DeWaters & Powers, 2013). This paper will now discuss each segment of Figure 1 and how these relationships are rooted in current research.

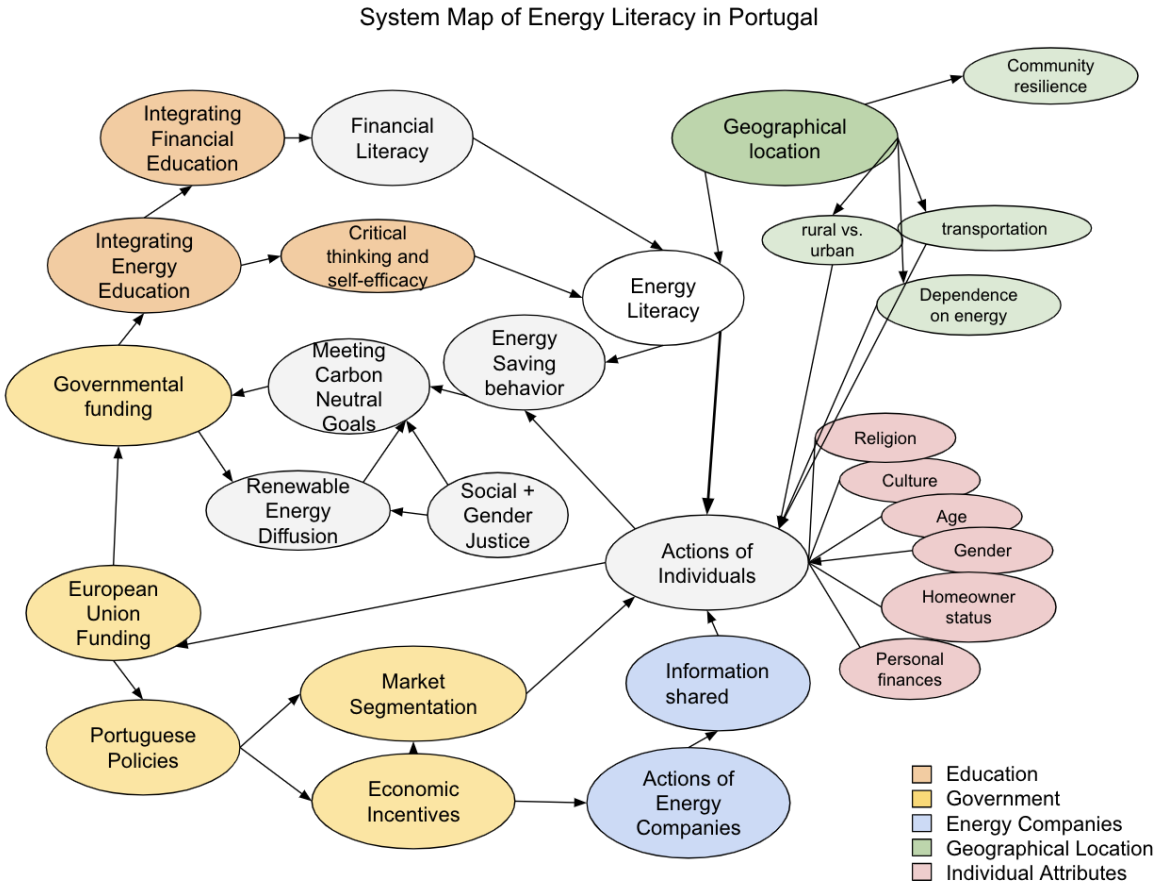

Figure 1: System Map of Energy Literacy in Portugal: Displaying the Relationships and Outcomes Between Social Institutions.
Source: own elaboration

5.1.1 Government and European Union

Starting on the bottom left of Figure 1, research shows the government plays a central role in the product of energy literacy (Negro et al., 2012). As a member of the European Union (EU), Portugal operates with periodic funding for social projects from the EU. National ministers from

Portugal adopt EU laws and create policies in line with the objectives of the larger European community. In terms of energy, which is a global resource, there is a direct impact on energy literacy from both the EU's recommendations and the way Portugal adapts these into policies. The responsibility for energy literacy falls on those who disseminate knowledge and, inversely, does not rely on the interpretations of already relatively disadvantaged people. Instead, creating long-term policy solutions to support innovative system solutions is how Portugal can remedy the system failure of low energy literacy levels.

Decades long research across Europe shows that cross-cutting strategies for training should be promoted and adopted, such as integrating energy topics into the education system, public campaigns to society, and utilizing platforms such as social media sources to disseminate knowledge to the public. To reach each part of the population, information can be segmented based on different literacy levels for the population in order to follow equitable and effective practices (Reis et al., 2021). Addressing the lack of trust and distance found between the population and the governmental institution, market segmentation in policy making can also impact the collective agency of populations. Segmenting information based on these relevant factors is more effective than 'one size fits all' policies (Barr, 2008).

In terms of the renewable energy transition, the government has a role in communicating the benefits of renewable energy and energy efficient technologies and adoptions to the public, as well as in the creation of economic incentives to drive adoption. It is also important to understand that energy awareness and consumption is a "culturally-mediated behavior", meaning that effective energy policies must reflect the cultural landscape and environment of the population (Cotton et al., 2021). Research shows that people tend to follow simpler solutions over more complex ones (Reis et al., 2021). The Portuguese government's policies can vary in terms of accessibility of adoption for the public. Making clear economic incentives is one way to galvanize public support, however these policies alone do not empower people towards energy literacy and making the best decisions possible.

5.1.2 Education System

The power of environmental energy education on energy literacy must not be overlooked, and therefore it plays a central role in determining energy literacy in Figure 1. Well-designed environmental education projects positively impact both the knowledge and attitudes of teachers and students regarding topics of energy literacy (van den Broek, 2019). These types of educational programs can assist in learning energy conversion calculations, understanding resources, and gaining awareness of personal consumption patterns (Morrisey & Barrow, 1984). It is improbable and unexpected that households have the information necessary to make financial-energy literate calculations. Higher financial literacy predicts higher levels of management regarding energy saving behavior (van den Broek, 2019). Due to this relationship, low financial literacy across Portugal presents a national concern in terms of lower energy demands and meeting carbon neutrality goals.

One of the most powerful empowerment tools brought about through education is the skill of critical thinking. Critical thinking is a requisite of problem solving, and both tools are essential for grasping energy literacy and applying one's knowledge to daily situations, energy issues, and behavioral actions (DeWaters & Powers, 2013). DeWaters and Powers (2013) stress the importance of internalizing the individual locus of control at a young age which will shape energy literate outcomes in the future. Fostering individual self-efficacy in the education system and through educational energy programs for all ages can be one avenue for increasing energy literacy in the future, as well as a factor explaining why energy literacy levels remain low today. Additionally, energy and conservation education must emphasize the habitual and consistent nature necessary to achieve real energy conservation change to see long-term benefits (Owusu-Manu et al., 2022).

Not all educational experiences of Portuguese students are the same. Depending on location, financial resources, and politics, the education that one receives and pursues is varied. Energy consumers with more quantitative academic backgrounds are expected to know the advantages and consequences of energy efficient behavioral changes in order to reduce energy costs (Reis et al., 2021). However, at large, there seems to be a gap between the suitability of the curricula offered by the education system and the real-life applications and industry demands (Lucas et al., 2018). In terms of what types of energy education programs are most effective, research shows that engaging with interactive technologies is more helpful than non-interactive learning programs (Huang et al., 2012; Bodzin et al., 2013). The role of public participation in social learning environments also functions as the connection between greater environmental citizenship and education. Environmental values are impacted by education and citizen engagement, and these are critical pieces to fostering energy literacy (Bull et al., 2008).

However, changes in the offered environmental education programs alone will not be sufficient for changes in the Portuguese population's energy literacy levels. Instead, pursuing a combination of educational and structural change is demanded as society transitions to a cleaner and low-energy society (Cotton et al., 2021).

5.1.3 Energy Suppliers and Distributors

Energy systems are complex systems since they can incorporate and extend across global resource flows, such as pipelines and cables crossing across countries and borders (Becker & Naumann, 2017). The energy system consists of interconnected parts from suppliers to distributors to consumers, making it difficult to place direct responsibility on any one actor in this system for promoting better energy literacy across consumers. In terms of being able to understand and interpret graphical information, Figure 1 argues that energy companies are responsible for providing data in non-misleading and understandable graphical formats.

It has been proven that people tend to greatly underestimate energy savings from high impact saving activities and overestimate savings from low-impact energy saving activities, such as turning off the lights (van den Broek, 2019). For this reason, energy companies can be

instrumental in providing the statistical insights and data necessary for consumers to understand ways in which they can become more energy wise. Although this may be counterproductive for the profits of energy companies, governments can instate requirements for the release of accurate, non-misleading data for consumers, an action that is in line with nationwide climate goals.

Increasing energy information transparency in energy consumption can be used to "nudge" and inspire consumers toward energy conservation behaviors. Providing feedback to customers regarding energy use behaviors can considerably reduce energy bills (Brounen et al., 2013). Behavioral nudges is a tactic that has been successful in influencing individual level energy consumption, and this paper suggests that applying behavioral nudges to a larger, macro-scale target can be instrumental in creating a change beyond the individual level. Energy companies house the data, analytics, and information necessary to the growth of consumer's energy literacy. Currently, energy companies are not held to a standardized process and format of relaying customer's consumption rates to them, and oftentimes people are confused in understanding their energy bills (SaveOnEnergy, 2020). Figure 1 identifies the role of energy companies as a leverage point to shifting individual energy consumer behaviors, when it is met with increased energy literacy.

5.1.4 Individual Demographics and Attributes

Individual demographics and attributes play a role in a person's energy literacy, such as gender, culture, religion, socio-economic status, as well as homeowner status and age. Although these attributes influence energy literacy, individuals are not responsible for the population's collective energy literacy levels. Instead, energy literacy levels across the population is a direct function of institutionalized practices and social systems. Additionally, the consequences and impacts of energy decisions are not weighed equally across the population, causing a landscape of injustice (CLEAN, 2021). Marginalized groups tend to suffer greater environmental impacts and tend to have lower resources for adaptive change, including access to clean and affordable energy, as well as educational programs that promote energy literacy.

In terms of gender, men have more energy and pollution knowledge than women, and women tend to have more optimistic attitudes towards energy conservation and governmental regulation (Gambro et al., 1999). In terms of religion, energy literacy is intimately linked to individual lifestyles including cultural and religious beliefs (van den Broek, 2019; Rohmatulloh et al., 2021). When investigating energy saving behaviors, it has been found that personal values and norms have strong influences (Shi et al., 2019). Since religion can often govern populations' behaviors and perceived norms, it is important to consider cultural aspects and norms into policy making is essential to their effectiveness and adoptability.

In terms of age, there is variance among awareness levels of the severity of energy problems. Younger students and adult consumers display different levels of knowledge and urgency regarding current energy events, economics, and resources (DeWaters & Powers, 2013). In additional research, age was positively correlated with the willingness to adopt an

environmentally friendly tariff policy, revealing that older respondents were more willing to adopt it (Reis et al., 2021). Also, homeowner status impacts the ways in which individuals recognize energy consumption through the interaction of paying energy bills. Significant differences in energy consuming behaviors have been discovered between people who own homes and people who live with family members or temporarily rent spaces (Reis et al., 2021). Energy related behaviors are also limited by personal finances and access to affordable energy-saving alternatives (DeWaters & Powers, 2013).

Figure 1 displays that each one of these personal attributes and individual circumstances impacts what actions individuals will be more likely to take. However, these attributes do not directly impact energy literacy levels, again, due to the systematic nature of institutionalized processes that create nationwide literacy levels.

5.1.5 Geographical Location

A study conducted by Lay et al. (2013) found that students living in urban areas scored higher on affective and behavioral energy literacy, however students in rural areas scored higher on cognitive energy literacy. Rural and urban communities commonly differ in many ways, such as in behavioral patterns of energy consumption based on climate and geographical zones. Rural communities tend to be smaller than urban communities, with less public transport, commercial, and medical infrastructure. For this reason, energy consumption around transportation is expected to be different based on an individual's geographic location. Communities have different levels of resilience and collective attitudes of local embeddedness, particularly in terms of energy supply and demand. Energy literacy programs and policies should take into account geographical differences and local knowledge.

5.1.6 Actions of Individuals

On the system map, actions of individuals refers to the energy consumption behavior of consumers. One dimension of energy literacy is action, such as the knowledge possessed by individuals to accurately assess the effectiveness of energy saving behaviors (van den Broek, 2019). Individual energy saving behaviors can be understood as actions of efficiency investments, improved management of current assets and appliances, curtailment of energy usage, and others. Research shows that when people understand their energy consumption behaviors, they are empowered to reduce energy use (Louis Zapico & Hedin, 2017). Through Figure 1, the key factors that influence individual behavior are related to energy education, geographical location, as well as demographic and socioeconomic characteristics.

Energy literacy levels impact the actions that individuals take, and in conjunction these two factors impact collective energy saving behaviors. Energy saving behavior across society leads to adaptation levels of renewable energies and energy conservation, which play important roles in meeting Portugal's decarbonization goals. Depending on specific indicators, the Portuguese

government will in turn receive funding from the European Union and both governmental bodies will continue to adjust fiscal allowances towards energy programs and the decarbonization sector. It is important to note, too, that social and gender justice will positively impact renewable energy diffusion and meeting carbon neutral goals.

5.2 Framework to Increase Portugal's Energy Literacy Through the Renewable Energy Transition

With a foundational understanding of the systematic landscape influencing and producing energy literacy, this paper now provides a framework moving forward for increasing energy literacy through the renewable energy transition in Portugal.

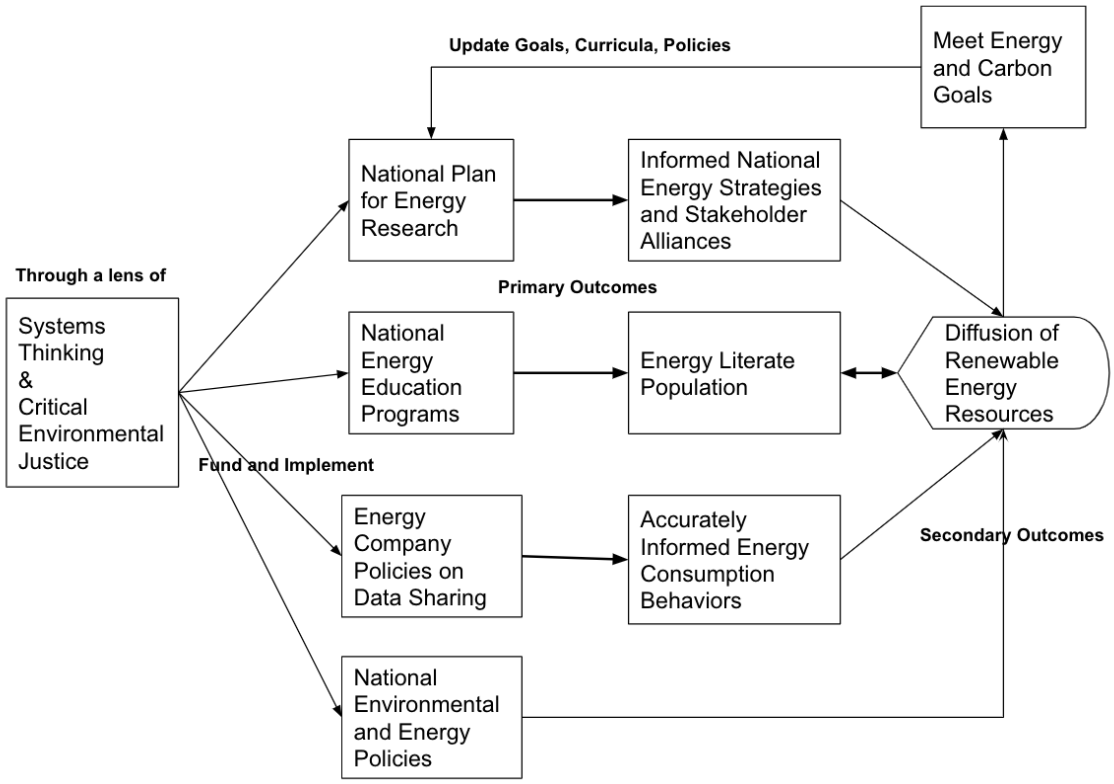

Figure 2: Conceptual Framework to Increase Portugal's Energy Literacy Through the Renewable Energy Transition
Source: own elaboration

5.2.1 Through a Lens of Systems Thinking and Critical Environmental Justice

Examining the causes behind the geographical distribution of energy illiteracy across Portugal is the first step to understanding sustainable and systemic solutions for the nation. Since state power has a tendency to reproduce and reinforce social inequities through new policies, this framework stresses the heuristic of critical environmental justice to be used in future energy policy making. Viewing energy literacy through a critical environmental justice lens means accepting

that this topic is intersectional in nature and is the product of multiple systems of oppression. Important to this theory is understanding the spatial and temporal distributions of energy and environmental illiteracy. The portions of the population that are marginalized and live without capital and vocational power should never be treated as expendable. It is in Portugal's best interest to fund and implement research and educational strategies that empower its citizens towards adopting sustainable behaviors and mindsets.

5.2.2 Fund/Implement & Outcomes

Politics, economics, education, and further research will play a strong role in the progress Portugal makes regarding the sustainable energy transition and increasing energy literacy among its citizens. As Portugal works towards ambitious decarbonization efforts, a greater understanding of the economic impacts this will have on the country will further support the decision-making necessary to make effective policies (Irena, 2016).

Starting with education, Portugal can create and instate a nationwide energy and financial education programs with equitable access and relevant and cutting-edge curricula. The kind of education will produce these effects operate under the following premises: (1) developing an awareness around natural and human components to current energy challenges and global state of climate change; (2) comprehension of the viability of all energy resources and their economic, environmental, and social impacts; (3) instill motivation and sufficient training for students to understand alternative energy strategies, from personal to global levels (Kandpal et al., 2014). Additionally, for highest success, these programs would be accessible to all citizens using different hybrid formats and languages. These programs can be housed in public community spaces, such as schools or libraries, and in online formats, potentially in conjunction with energy companies and suppliers. More education system improvements include better education on energy taxes and how these taxes relate to the country's decarbonization goals to promote a more realistic sense of trust, progress, and impact.

Also, it is essential that a widely agreed upon definition is developed, as well as agreed upon indicators, so that data can be standardized across communities and populations in Portugal and beyond. Increasing funding and capacity to support energy literacy research is also in the best interest of Portugal's climate and social change goals. Additionally, the use of community engagement in a national energy research strategy should be considered. In terms of the state of global climate change and rising energy demands, there is an urgency to instate energy literacy programs and policies across Portugal. To promote the swift diffusion and implementation of these improvements, establishing multi-sectoral stakeholder alliances in communities and across the nation will be helpful. Additionally, there is an urgency to address energy justice matters across Portugal, especially given the high energy poverty rates. Further, an investigation into how improvements in equity and energy poverty will impact energy literacy and energy empowerment is of interest to understanding the functions of Portugal's systemically rooted institutions.

Public policies can take the form of time-bound, credible targets and utilize market-based mechanisms to keep pace with changes in the electricity sector (Irena, 2016). Environmental policies should not just be evaluated on their environmental effectiveness, economic efficiency, dynamic efficiency, revenue generation, and enforcement, but instead with a heavy focus on equity, fairness, and moral considerations of the policies (Meireles, 2022). Policies should be continually reviewed on measures of effectiveness and adjusted with subsequent alterations as needed (Negro et al., 2012). Energy literacy has sectoral connections to climate justice, human empowerment, environmental economics, public health, and environmental justice. There are challenges in increasing and refining the facilitation of renewable energy education across society, namely the sector wide shortage of professionals in this field. Creating policies that increase the readability of information, energy data, and graphs is possible and should be enforced to promote energy literacy (Reis et al., 2021). As an opportunity for increasing gender representation, there is a hopeful sight in the high interest of females in renewable energy education to work in defiance of this shortage (Lucas et al., 2018). Increasing gender representation in the energy sector is vital to the success of the energy transition, as right now women make up 32% of renewable energy workers and only 22% of the global workforce in conventional sectors (Mikkonen et al., 2020).

5.2.3 Building a Sustainable Framework and Overcoming Barriers

Justice, equity, and community engagement are all facets inherent to understanding and changing energy literacy. Access to energy and financial education programs, the accessibility of knowledge and relevant data, local production, and the critical thinking skills necessary to make energy wise decisions are all pivotal factors in shaping energy literacy that are not evenly distributed across society. Some populations and groups of people have better access to the resources and tools necessary to increase individual energy literacy levels. When considering a nationwide energy literacy framework, there is a need to stimulate initiatives for energy democracy and justice, which further supplements the efforts of the “right to the city” movement (Becker & Naumann, 2017). There are existing barriers to literacy and energy sustainability including the lack of fiscal, human, and technological resources, as well as lower institutional capacities (Irena, 2016). Moving forward, it is important to better understand and address these barriers, as well as emphasize the foundational rebuilding of trust in alternative energy providers. Trust can be built through continuous supervision and validation by a third party of companies’ code of ethics and sustainability efforts, as well as through providing affordable, consistent energy to consumers (Mikkonen et al., 2020).

The diffusion of renewable energy technologies has been faced with many socio-cultural, economic, and institutional challenges. Research shows that one way to overcome these barriers is to increase ‘energy consciousness’ among customers, policy makers, and other stakeholders (Kandpal et al., 2014). So, increasing energy literacy will have an impact on the speed of renewable energy diffusion. Energy education that encompasses renewable energy technologies is being one of the biggest solutions to the dissemination of renewable energy technologies. Notable to mention,

each part of this framework relies on human capacities. The human factor in this framework allows for the creation and execution of socially aware and innovative solutions. Cooperation among sectors and policies, as well as effective communication will increase civic engagement and progress towards energy justice, accessibility, and literacy (Mikkonen et al., 2020).

6. Conclusion

Society is faced with increasing energy demands, a growing population, and the onset of climate change ramifications (International Energy Agency, 2019; Ambrose & Sheffield, 2020). Some of the biggest problems facing the world today are system failures in the landscape of social institutions, such as the presence of energy illiteracy. Energy literacy cannot be solved by fixing one system in isolation from other systems. Energy literacy is a key function in a society-wide paradigm shift towards energy transparency, individual empowerment, and consumption behavior in line with decarbonization goals. The current energy system is amalgamated with the capitalist structure, and the renewable energy transition creates the opportunity for paradigm shifts, greater energy activism, and positive social change towards a decarbonization mindset. Additionally, the energy transition provides the space for new strategies on energy policy, as well as opportunities for more jobs, improved welfare, and new sources of growth (Becker et al., 2017; Irena, 2016).

By creating a system map of the systemic and institutional causes of energy literacy levels, this research is providing the grounds to create sustainable, long-lasting solutions to increase energy literacy. Moving forward, it is recommended that Portugal places the responsibility of energy literacy levels not on individuals, but on the institutions that shape individuals, such as education and politics. Economic factors greatly influence company and individual behaviors related to energy. Therefore, new policies should encourage economic growth as indistinguishably linked with sustainable development and climate-wise practices (Owusu-Manu et al., 2022). Energy education on renewable energy technologies remains one of the biggest solutions to the dissemination of renewable energy technologies.

There is potential for harmonization among the built and natural environments related to energy literacy and energy consumption behaviors, and this change is a matter of nationwide, locally-focused, and culturally-minded education and policies. Although limited to a Portugal case study, the findings of my research can be used to inform policy and regulations at the national level in understanding the root causes for energy literacy levels and a framework to increase them to empower people and countries to reduce energy demands. Special emphasis should be placed on the intersection of energy, justice, and social inclusion (Lennon et al., 2019). Future direction for research include: (1) gaining nationwide data on energy literacy to establish baseline data, as well as the establishment of accurate indicators that are feasible nationwide; (2) crafting policies related to the energy company-consumer relationship to breed trust and the dispersal of non-misleading and information; (3) investigation into other leverage points aligned with the renewable energy transition and increasing energy literacy; and (4) more research on the relationship between energy literacy and attitudes towards decarbonization goals.

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