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Why don't we consume energy more efficiently? a Lisbon Parish council case study

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Introduction: Almost 50% of the European Union's final energy consumption is used for heating and cooling, 80% of which in buildings. The European Commission recently issued the "Efficiency Energy First Principle," a formal recommendation to EU countries prioritizing energy efficiency measures over other energy-related investments. Decarbonizing the aging housing stock represents a significant challenge to Southern Europe and the remaining Member States. This exploratory research aims to understand why Portuguese people fail to increase their energy efficiency; it then proposes potential interventions. Several studies have looked into the effect of technology-based and behavior-based strategies (individual, socioeconomic and demographic, as well as contextual factors) regarding residential energy consumption. Few, however, have brought all these factors together in one project as in this case.

Methods: We used the integrative COM-B model to investigate three core influences of behavior, namely, capability, opportunity, and motivation in a qualitative analysis of a sample of citizens of one specific Lisbon, Portugal community. The Behavior Change Wheel model was then used to propose interventions that might promote energy-responsible behavior.

Results: Our finding suggests that investments in structural strategies, and, above all, in behavioral strategies are needed to achieve efficient residential electricity consumption. Specifically, we found a lack of capability (i.e., people's physical skills and strength, knowledge, and regulation skills) represented the greatest barrier to energy consumption efficiency. A lack of motivation (involving habits and self-conscious intentions or beliefs) was the least decisive factor in the adoption of efficient energy consumption behaviors.

Discussion: We therefore recommend the following interventions: 1) training and enablement addressing residents' physical capability (primarily the replacement of high consumption equipment); 2) training, restriction, environmental restructuring, and enablement would increase residents' physical opportunity (arising from poor home insulation and citizens' lack of financial resources to invest in energy solutions); and 3) education, training, and enablement to change psychological capability (regarding insufficient or confusing energy use information).

KEYWORDS

residential electricity consumption, COM-B model, change wheel model, public policy, behavioral intervention

1 Introduction

Energy is the lifeblood of modern societies, and it has been instrumental in propelling human development and progress across the globe. Its versatile applications have fueled economic growth, technological advancement, and improved living standards (Pablo-Romero and Sánchez-Braza, 2015). However, energy overuse has come at significant environmental cost, contributing to climate change, resource depletion, and other environmental challenges (Dincer, 1999; Dias et al., 2006; Bilgen, 2014; Khalili et al., 2019; Martins et al., 2019; Alharthi and Hanif, 2021). As the world grapples with the urgent need to address these issues, energy efficiency promises to make significant contributions toward achieving sustainable levels of energy consumption (Brookes, 1990; De Almeida et al., 2016; Worrell et al., 2018; Economidou et al., 2020; Paramati et al., 2022; Zakari, et al., 2022).

Upon the reworking of the European Commission's Energy Efficiency Directive in 2021, the "Energy Efficiency First Principle" established optimized energy use as one of the central pillars of the union's energy policy. With a formal recommendation to EU countries and detailed guidelines on its application, it offers a strategic framework to prioritize behavioral interventions as a bridge to optimize energy use, reduce wastage, and mitigate environmental impact. Setting energy efficiency as a central goal promises a multitude of benefits can be attained, including cost savings, reduced carbon emissions, and enhanced energy security (Gillingham et al., 2009; Ryan and Cambell, 2012; Kerr et al., 2017; Gökgöz and Guvercin, 2018; Thema et al., 2019).

Most buildings in Portugal (77%), as in other southern European countries, are residential and were built before 1980 (53.5%), i.e., before the first energy saving regulations for building. As a result, their energy performance is generally low (Monzón-Chavarrías et al., 2021). Despite appreciable progress in increasing renewable energy production in Portugal, dependence on imported natural gas is an ongoing problem (Martins et al., 2022). Optimizing energy consumption is thus critical. Several tangible and intangible actions have been undertaken to increase energy efficiency in Portugal including various funding programs such as the PPEC[1], FEE[2], IFRRU2020[3], and the Environmental Fund[4]. Yet, further action is still needed to reduce household energy consumption. Portugal's investment in energy efficiency lags behind that in renewable and environmental energy programs, and this project addresses the need to prioritize research into the behavioral aspects of energy consumption (Silva et al., 2017; Gassar and Cha, 2020; Martins et al., 2020).

Through qualitative research and data analysis, this investigation delves into the complexities of human behavior related to energy consumption in Portugal. Behavioral change cannot be reduced to levels of awareness. However, focusing merely on behavior to the expense of contextual or situational factors constrains our view of energy consumption. Hence, by exploring different factors hindering or promoting energy efficiency, this paper proposes targeted behavioral change initiatives aligned with the nation's energy goals, thereby contributing to a more sustainable future. This project aimed to identify key barriers to efficient electricity use in the residential context utilizing the COM-B and Change Wheel models as frameworks for potential behavioral interventions. The novelty of the methods (as well as our findings and proposed interventions) may help other researchers and policymakers of countries in similar circumstances to make appropriate decisions.

By examining Portuguese energy consumption behaviors and attitudes, this research intends to contribute to environmental studies and practices, to (indirectly) evaluate the effectiveness of previous public policy investments, and to pave the way for more successful future behavioral change campaigns. Understanding these complexities is essential to promoting sustainable energy use and driving meaningful change on a broader scale, despite the inconsistency of behavior and the high level of variability in consumption levels between buildings (Lopes et al., 2012a).

Understanding human behavior (behavioral patterns, motivations, and barriers) and its impact on energy consumption is pivotal for designing effective energy efficiency strategies (Abrahamse et al., 2005) and encouraging responsible use. Behavioral and attitudinal changes hold huge potential for reducing domestic energy demand. However, little theoretical consideration has been given to date to an empirical assessment of household pro-environmental behavior and its drivers (Belaïd and Joumni, 2020).

In short, this study aims to help researchers and policymakers foster sustainable practices and informed policy decisions regarding residential energy consumption by applying an innovative (holistic and integrated) methodology that aligns the behavioral approach with the latest European guidelines.

2 Materials and methods

2.1 Literature review

Clear signs abound of consumers' intentions to inhabit eco-friendly homes (favorable attitudes toward eco-friendly homes, high control in the ability to purchase eco-friendly homes, and self-identification of green consumerism) (Hong, 2013). In addition, the public's awareness of the value and need for sustainable energy practices at both the individual and collective levels have been growing. Nevertheless, the high levels of current energy use in housing suggest a gap exists between people's intentions and behaviors. Consumers still struggle to realign their behavior particularly over the longer term, even in the presence of financial incentives (Frederiks et al., 2015). This raises doubts about which determining factors are preventing efficient residential energy consumption and whether policymakers are addressing them in the best manner.

1 Plan to Promote Efficiency in Energy Consumption (Plano de Promoção da Eficiência no Consumo de Energia—PPEC), at: https://www.erse.pt/en/communication/highlights/erse-discloses-the-measures-under-implementation-of-the-7th-edition-of-ppec-available-to-consumers/.

2 Energy Efficiency Fund (Fundo de Eficiência Energética–FEE), at: https://www.pnaee.pt/fee/.

3 Financial Instrument for Urban Rehabilitation and Revitalization (Instrumento Financeiro para a Reabilitação e Revitalização Urbanas - IFRRU), at: https://ifrru.ihru.pt/web/guest/home-en1.

4 Environmental Fund (Fundo Ambiental, at: https://www.fundoambiental.pt/.

Energy behavior refers to those actions that lead to end-use energy consumption (Lopes et al., 2012b), while energy efficiency, can refer not only to the adoption of technologies to reduce overall energy consumption, but also the way said technologies are used, according to consumers' energy behavior (Lopes et al., 2012a, p. 4096). Some authors, however, associate energy conservation to the behavioral change that leads to energy savings and refer to energy efficiency as the adoption of technologies without necessarily changing target behaviors (Oikonomou et al., 2009).

Residential energy consumption is a complex socio-technical phenomenon shaped by various interrelated factors (Belaïd and Joumni, 2020, p.2). Such complexity has given rise to different frameworks from multidisciplinary fields. Psychology, economics, and sociology have focused on energy behaviors, while architecture and engineering research has investigated consumption from a technological perspective. These multiple viewpoints have resulted in ambiguities or partial understandings of residential energy consumption. Despite the increase in researcher attention from a wide range of fields into household energy consumption and its correlates (Volland, 2017), little understanding has yet been achieved of energy savings based on behavioral and attitudinal changes (Belaïd and Joumni, 2020). Said alterations are known to be critical to the deployment and expansion of energy efficient technologies and the sustainability of energy systems (OECD, 2016. Nevertheless, integrated, and multidisciplinary approaches remain in demand (Lopes et al., 2012a).

Behavior-based strategies focus on changing consumers' energy-related behaviors (Steg, 2008), and they appear to be more cost-effective than technology-based strategies since they require less initial investment (Vassileva et al., 2013). Lutzenhiser (1993) and Sovacool (2014) highlight that although technological advances are clearly important to promote energy conservation (allowing the use of less energy, through insulation and windows, for instance) and efficiency (e.g., replacing incandescent lighting) behavioral factors are each time more recognized as deeply significant regarding energy conservation (Zhou and Yang, 2016). Moreover, previous findings have revealed that even when a building's design might promote efficient energy consumption, user behavior in fact prevails, putting those benefits at risk (Steinberg et al., 2009). As Lopes and Antunes (2022) state "the focus has moved from predominantly technological and financial issues (the so-called physical–technical–economic model) to the pursuit of more integrative approaches encompassing social changes" (p.1). Therefore, identifying what needs to change is crucial for the development of effective behavior change interventions, as it will inform which behavior change techniques or content to include in programs, communication campaigns, and/or materials.

Behavioral intervention strategies can be classified into antecedent and consequence strategies (Abrahamse et al., 2005). The former prevents undesired behaviors (e.g., commitment and goal setting), enable learning and produce immediate results (Bambara and Kern, 2005). The latter type, in turn, influences household energy saving outcomes by providing a reward for energy-saving behavior such as feedback or monetary rewards (Nolan et al., 2008; Ferguson et al., 2011).

Parajuly et al. (2020) pointed out the existence of more than 80 different theories of behavior and behavioral change across the fields of psychology, sociology, anthropology and economics Darnton, 2008; Davis et al., 2015). Therefore, it is not surprising to find that most energy-use behavioral studies arise from within the social sciences and can be categorized in different ways, such as individual, socio-demographic, and contextual or situational factors (Ding et al., 2017). Environmental psychologists emphasize individual factors, as did Steg, (2009) who focused on motivational and contextual factors and individuals' habitual behavior). Individual factors may include household habits and time in households, as well as self-interest (Darnton et al., 2011; Ohler and Billger, 2014; Belaïd and Joumni, 2020). Both factors are predictors of energy-consumption, or even energy literacy (Reis et al., 2021). Risk and trust attitudes are also linked to household energy use. Specifically, higher risk tolerance leads to increases in residential energy use, and trust is negatively correlated with household energy demand (Volland, 2017).

Sociologists, on the other hand, highlight the social impacts on decision-making, seeing energy use as a result of social learning, e.g. (Wilson and Dowlatabadi, 2007), or the influence of leaders (Hewitt, 2022, for instance). Social psychologists, meanwhile, focus on socioeconomical and demographic factors, including family size, income level (Sardianou, 2007), household and dwelling characteristics (Belaïd and Garcia, 2016), home appliance types and efficiencies (Gadenne et al., 2011; Ding et al., 2017). In fact, sustainable housing and associated technologies have been found to have a much higher influence on energy use than occupant attitudes (O'Callaghan et al., 2012).

Another branch of investigation looks into contextual influences on environmental behaviors. Such factors may be energy prices, access to delivered energy, climate, energy sources and energy-related policies, or even cultural activities (Ertz et al., 2016; Quaglione et al., 2017; Belaïd and Zrelli, 2019). For instance, using micro models and those employing residential and commercial data, Labandeira et al. (2006) found that agents react somewhat to changes in energy prices. , although, more in the long rather than the short term, and this pattern was revealed to be is similar among different energy products. Studies of household-level data, Reiss and White (2008) demonstrated that energy price caps following market shocks they precluded substantial and rapid energy use reductions. In 2021, Xu et al., 2021 proposed an option-based strategy that would offer buyers (i.e., households) an opportunity to earn rewards according to the degree to which they achieve pre-determined energy saving goals. Their Household Energy Saving Option (HESO) framework consists of five elements: theoretical foundation (T), integrated interventions (I), market premises (M), energy sustainability (E), and stakeholders (S). It should be asked, however, whether this consumption dip results from more efficient or sustainable behavior or perhaps self-limitation. The risk is that when electricity prices fall, the earlier behavior may return. As Steg (2008) state "If people only conserve energy for hedonic or cost reasons, they will stop doing so as soon as the behavior is no longer attractive or cost-effective" (p. 4450). The same authors observed that conservation appeals, and informational programs produce sustained reductions in energy demand (idem).

The proposed categorization from Ding et al. (2017) is in line with the findings of Parajuly et al. (2020). According to the latter authors most common theories and models of pro-environmental behaviors can be categorized as either moral (such as the Value-belief-norms Theory), rational (e.g., the Theory of Planned

Behavior), economic models (willingness to pay) (Turaga et al., 2010)—individual factors; or make use of cognitive biases (nudging)—contextual factors; and social influences (Thaler and Sunstein, 2008; McKenzie-Mohr, 2011)—social factors.

Recent years, holistic approaches (and appeals) have begun looking into energy use. For instance, after reviewing the literature related to individual household energy consumption, Pothitou et al. (2016) pointed out that energy perception gaps are affected by psychological, habitual, structural, and cultural variables along a wide contextual, meso-societal, and micro-individual spectrum for a variety of combined intervention methods. More recently, Moezzi and Lutzenhiser (2020) called for the development of interdisciplinary methods of energy research which might enable engineers and social scientists to work together.

2.2 Methodology

2.2.1 Case study

This is an exploratory, qualitative study that uses a bottom-up methodology and extrapolates the results to an urban scale. Specifically, the study focused on the Penha da França civil parish in Lisbon, Portugal. Over the years, tangible and intangible actions have been undertaken under the auspices of the PPEC (Plan for the Promotion of Efficiency in Electricity Consumption)[5] to enhance Portuguese energy efficiency. Other similar initiatives including the Energy Efficiency Fund (FEE)[6], and Financial Instrument for Urban Rehabilitation and Revitalization 2020 (IFRRU 2020)[7] have significantly contributed to improving energy efficiency in buildings and supporting sustainable development in urban centers. The 2016 Environmental Fund[8] replaced four others including the FEE and aims to support environmental policies and help Portugal achieve national and international environmental goals. The "More Sustainable Buildings" initiative and the Efficiency Voucher Program have also promoted sustainability, combated energy poverty, and contributed to increased energy efficiency in residential buildings.

From 2007 to the present, our research shows that the Portuguese government has invested nearly 800 million euros in programs designed to renovate thermal insultation, install renewable energy sources, and acquire more efficient equipment. Despite the significant impact of the IFFRU fund on residential building renovation and increased energy efficiency, it is now essential to diversify investments and to broaden programs' focus and to further reduce unnecessary household energy use. Sustainable trends and continued progress depend on the effective formulation and implementation of energy efficiency policies in conjunction with economic efforts.

2.2.2 Variables used in the study

"The improvement of the energy and environmental performance of buildings calls for innovative research, new policies and standard regulation, new materials and technologies, the integration of renewable energy sources and increased outreach and people awareness (designers, practitioners and end-users)" (Soares et al., 2017) p.845). However, increased outreach and consciousness raising are not sufficient to change behavior. Moreover, it is not enough to merely identify the impact of individual characteristics and socio-demographic factors, while neglecting the impact of contextual or situational ones, as seen in the previous literature review. For these reasons, we opted for an integrated and holistic approach to answer the question "Why do not the Portuguese consume energy more efficiently?"

Formulated to address the limitations of previous frameworks, the COM-B is an integrative model of behavior change that describes the influences on behaviors (Michie et al., 2011). It encompasses three core behavior influences, chosen deliberately to be applicable across a broad spectrum of intervention types. 1) Capability assesses people's physical skills, strength and psychological capacities such as knowledge and regulation skills. 2) Opportunity looks into both social and physical facilitators; and 3) motivation focuses on automatic processes such as habits and reflective processes like self-conscious intentions or beliefs such as risk perception. Identifying these influences can lead to a better selection of the content or techniques to be included in behavior change campaigns (Michie et al., 2011; 2013). Once researchers have performed the COM-B, the Behavior Change Wheel (BCW) can be applied to synthesize 19 behavior change frameworks identified during systematic literature review (Michie, van Stralen, et al., 2011; Michie et al., 2014). It is constituted with three layers: hub determines the behavior sources to be targeted for intervention. The second layer lays out nine intervention functions that can be chosen to address deficits in one or more of type of capability, opportunity, or motivation, namely,: education, persuasion incentives, coercion, training, enablement, modelling, environmental restructuring, and restrictions. In the outer layer seven policy categories can be used to implement interventions, namely, environmental and or social planning, communication and/or marketing, legislation, service provision, regulations, fiscal measures, and guidelines (Michie et al., 2014). One advantage of this model is that its complementary framework helps determine needed interventions and policies.

The COM-B model and the identification of corresponding behavior change techniques have been used successfully in behavior change interventions across multiple behaviors, especially in public health (such as to understand the potential roles of digital interventions in encouraging children's outdoor play (Khalilollahi et al., 2022)) and to examine existing campaigns with the view of optimizing them (e.g., West et al., 2020). The model is beginning to find use as well in other fields, such as–the development of crowd messaging for public transport (Krusche et al., 2022), or to

5 PPEC (Plan for the Promotion of Efficiency in Electricity Consumption). Available online: https://www.dgeg.gov.pt/pt/areas-setoriais/energia/eficiencia-energetica/financiamentos/plano-de-promocao-da-eficiencia-no-consumo-de-energia-eletrica-ppec/(accessed on 1 August 2023).

6 (FEE) Energy Efficiency Fund. Available online: https://www.pnaee.pt/fee/ (accessed on 1 August 2023).

7 (IFRRU 2020) Financial Instrument for Urban Rehabilitation and Revitalization 2020. Available online: https://ifrru.ihru.pt (accessed on 1 August 2023).

8 Fundo Ambiental. Available online https://www.fundoambiental.pt/ (accessed on 2 August 2023).

assess behavioral influences behind households' transitions to cooking with cleaner fuels (Perros et al., 2022). No record exists to date of Michie's work being applied to study energy use. It is our belief that enables investigators to combine individual, structural, and social factors (i.e., the micro, meso, and macro levels) will therefore be of great benefit for determining constraints on a desired behavior. In fact, the conceptualization of the three constructs that composes the model was deliberately rather broad to facilitate its application to a range of different types of intervention and corresponding policies for their implementation. Moreover, it is the only behavior change model that includes a complementary framework that helps identify needed interventions and policies.

This model was therefore chosen to identify which of the three necessary conditions for a behavior to occur is preventing or hindering efficient energy use. This study investigated the impact of participants' physical skills and strength, psychological capability, and regulation skills (capability), social and physical facilitators (opportunity), and automatic and reflective processes (motivation), to understand why they found it difficult to consume energy (i.e., electricity) more efficiently (meaning, the use of resources without waste).

2.2.3 Data collection method

Together with Pothitou et al. (2016) it is our belief that research should start from local scale and expand towards the regional one. The chosen methods helped deepen our understanding and effectiveness and only then was this expanded within a wider group, and ultimately towards the whole community. "This will permit regional policies to be successfully framed as they will capture the virtual needs of the local society. Combining the common characteristics of the different local implementations of the framework would enhance them into a wider pluralistic framework for meeting greenhouse gas emissions and fuel poverty targets as well as domestic targets in respect to household energy reduction" (Pothitou et al., 2016, p. 698).

To this end, the study sample was defined based on the socio-demographic information provided by the Parish Council of Penha de França (Lisbon) with the goal of obtaining a degree of representativeness of 0.1% of the Universe under analysis. The Penha de França Parish Council is very traditional in the Portuguese capital, being created in 1918. According to European Anti-Poverty Network, Portugal (EAPN)[9], it has more than 2.20 km^2 of area, and almost 28,000 inhabitants (15,497 female and 12,470 male) (Portugal, 2023), making representative of the general Portuguese population. According to Censos 2021 (INE, 2021), the Parish Council has 17,710 households and 2,425 buildings.

Focus groups (Krueger and Casey, 2000; Rabiee, 2004) collected data which were treated using thematic categorical content analysis by way of the MaxQDA software. Specifically, four focus groups (FG) were conducted, lasting between 60 and 90 min, between June and July 2022, in Lisbon. Two groups had seven participants, one session had four, and the other six, making a total of 23 participants, 14 of which were female and nine male. The youngest was 22 years of age and the oldest was 75. They represented socio-economic classes C1 (14) and B (9) (see attached tables) and were recruited and incentivized with the support of a market research company that randomly distributed them over the four sessions. All participants signed a consent form.

Each FG had a moderator and an observer. Using a previously designed script (see appendix), the moderator asked questions and explored the COM-B model issues, namely, education, persuasion, incentives, coercion, training, enablement, modelling, environmental restructuring, and restrictions. Sessions were recorded in mp3 format and transcribed into a Word document. Content analysis (Bardin, 1977) then took place using the MaxQDA computer software (Kuckartz and Radiker, 2019). A categorical analysis using an *a priori* definition of the three COM-B model categories described above: Capability was subdivided into physical and psychological categories. Opportunity comprised the social and psychological groupings, while motivation encompassed the automatic and reflexive. We also chose to classify the text segments (sentences) considering the category blockers. The clipping was caried out based on the identification of the text segment (unit: sentence), which in turn was coded and classified by two coders. Next, aggregate data were processed by the computer program, yielding quantitative frequency data and a and a comparison of occurrences, which enabled us to use a qualitative approach to answer the research question.

TABLE 1 General results: Categories, sub-categories, and text segments' quantification.

	Total		Total
Opportunity	46	Physical Opportunity	33
		Social Opportunity	13
Capability	64	Physical Capability	48
		Psychological Capability	16
Motivation	22	Automatic Motivation	14
		Reflective Motivation	8

3 Results

3.1 Study 1—Application of the COM-B model

Table 1 illustrates that the main factors hindering efficient energy consumption were mainly due to a lack of capability–people's physical skills and strength and psychological capability such as knowledge, and regulation skills, as indicated by the 64 text segments mentioning this factor. The second most commented factor was opportunity, which comprises both social and physical facilitators. The most frequently mentioned obstacle fell into the physical capability category, followed by those in the physical opportunity group. On the other hand, our findings also revealed that the lack of motivation, involving automatic processes such as habits and reflective processes including

9 In https://observatorio-lisboa.eapn.pt/freguesias/penha-de-franca/ (accessed on 1 August 2023).

TABLE 2 Mapping of COM-B to the TDF domains and Frequency of Text Segments.

Category	Sub-Categories	Theoretical domains Framework (TDF)	Text Segments
Opportunity	Physical Opportunity	Poor residential thermal insulation	13
		Lack of financial resources to invest in energy solutions	9
		Logistical constraints to apply efficient energy solutions	6
		Lack of time to evaluate or apply alternative solutions	3
		Poor solar orientation of the home	2
	Social Opportunity	Inefficient energy use of other household members	9
		Resistance of landlords to insulating the house	3
		Assistance to family members using electrical equipment	1
Capability	Physical Capability	Use of high-consumption equipment	23
		Not turning off equipment or lights when not needed	13
		Excessive use of electrical equipment	8
		Remote work	4
	Psychological Capability	Lack of information or confusing information about energy expenditures	6
		Ignorance of the advantages of small gesture of change	4
		Lack or little training in sustainable energy consumption	2
		Difficulty in finding energy solutions or excessive bureaucracy	2
		Perceived inability to change	1
		Lack of knowledge in the use of electrical equipment	1
Motivation	Automatic motivation	Lack of concern or forgetfulness of small gestures	8
		Laziness or lack of interest in exploring solutions	6
	Reflective motivation	Perception of lack of cost effectiveness	3
		Lack of environmental awareness	3
		Fear of change (e.g., electricity supplier)	1
		Perception of exogenous difficulties in switching to energy solutions	1
		Perceived inability to change	1
		Lack of knowledge in the use of electrical equipment	1

self-conscious intentions or beliefs such as risk perception was the least decisive factor in the adoption of efficient energy consumption (22 text segments identified).

Table 2 details results according to the six categories (Physical Opportunity, Social Opportunity, Physical Capability and Psychological Capability, Automatic Motivation and Reflective Motivation), respective subcategories, and theoretical domains. It is important to point out that all theoretical domains emerged naturally from the focus groups and were not previously defined by the researchers. These include constructs aligned with those mentioned in earlier theories such as household habits and time in households (Ding et al., 2017), access to delivered energy and energy sources (Ertz et al., 2016), family size or even home appliance types and efficiencies (Belaid and Garcia, 2016). Other behavioral constructs also appeared such as memory, knowledge (energy literacy), skills, beliefs about capabilities and consequences, and emotions, that have yet to be delved into by the literature.

In the Opportunity domain (that involves both social and physical facilitators), the most relevant factors in the Physical Opportunity category included poor thermal insulation of the home (e.g., "regarding saving techniques, I have an old house. I have a lot of insulation problems") and the lack of financial resources to invest in energy solutions (e.g., "I do not have that money . . . to invest . . . to be energetically autonomous . . ."). The Social Opportunity category encompassed the inefficient energy use of other household members was the most frequently mentioned (e.g., "because I cannot control my kids if they're leaving the PlayStation on for 2 h when I'm not at home").

Regarding the (in)capability (people's physical skills and strength and psychological capability such as knowledge, and regulation skills) to improve the efficiency of energy consumption, the use of high-consumption equipment (e.g., "and one of the things that also costs a lot, and that lady already said, is the air conditioning, and the oil heater. Oil heaters are crazy") and the lack of information or confusing information about energy

expenditure' "I'm not very knowledgeable about how to save") are the most frequently mentioned reasons.

Motivation (automatic processes such as habits, and reflective processes such as self-conscious intentions or beliefs such as risk perception) to adopt energy-efficient behaviors is inhibited by a lack of concern or forgetfulness with small gestures (e.g., "and sometimes I make a mistake which is to leave the air conditioning on in the morning or in the afternoon") and by the perception of a lack of cost effectiveness or lack of environmental awareness (e.g., "someone has already done the math for me and the difference was so small that it was not even worth it . . . they were some, they were an insignificant thing").

Applying the COM-B model (Michie et al., 2011) allowed us to obtain an intuitive and structured perspective of domestic energy behavior (Mayne, 2018). Physical capability was identified as the major barrier to efficient consumption, followed by physical opportunity, and psychological capability. Regarding physical capability, the use of high consumption equipment was found to be an important issue, while physical opportunity was most highly associated with poor home insulation and lack of financial resources to invest in energy solutions. Psychological capability, in turn, was mainly related to the lack of information or confusing information about energy expenditures.

This study thus corroborates previous findings suggesting that domestic energy-consumption is driven by a range of factors, including individual, contextual or situational, and socio-demographic ones (Ding et al., 2017 which illustrates the complexity of factors and perceptions in attitudes toward domestic energy use (Belaïd and Joumni, 2020), and consequently the difficulty in dealing with inefficient electricity use.

3.2 Study - 2 - application of the behavior change wheel

We then used the Behavior Change Wheel (BCW) to identify possible interventions. The BCW can be applied across levels from individuals to groups, sub-populations, and populations, and within different organizational structures and systems, by following three steps: 1) understanding the behavior; 2) identifying intervention options; and 3) identifying content and implementation options, namely, behavior change techniques and delivery mode. In other words, once behavioral restraints are understood, the BCW can help design interventions to be embedded in policy categories designed to change those restraints at different levels considering their interactions and interdependencies. For instance, based on what is known about the macro-level target behavior, the wheel can help identify current or new key policies and regulations addressed geared to the population-level. At the meso level, the focus is on social structures that influence behaviors within a specific social context or community. Training and education, or even work with organizations and community leaders (actions that promote community engagement or participatory approaches) are methods that create supportive social structures. Micro-level individual behavior change involving the psychological and cognitive factors include the use of techniques such as self-monitoring, feedback, goal setting, and persuasion.

These findings elucidated the three most commonly mentioned obstacles or relevant COM-B components to achieve the desired change (efficient energy consumption), we propose the following interventions.

- Physical Capability (associated mainly with the use of high consumption equipment): Training and Enablement (e.g.,: promotion of energy consumption practices, and reduction of taxes on the purchase and continued use of efficient equipment);
- Physical Opportunity (mostly associated with poor home insulation and lack of financial resources to invest in energy solutions): training, restriction, environmental restructuring, and enablement (e.g.,: regulatory monitoring of the validity and accuracy of household appliance energy labels; incentives to make homes more efficient; benefits (e.g., vouchers, discounts, protocols, etc.) for those who use efficient equipment. by was of
- Psychological Capability (essentially related to the lack of information or confusing information about energy expenditure): education, training, and enablement (e.g.,: advertising with energy saving guidelines through media; tax reductions on the purchase and continued use of efficient equipment).

Table 3 contributes to the debate about how each intervention might be operationalized through specific policy categories, whose duration would be determined by monitoring results throughout the process. Our findings coincide with those of Steg (2008): psychological strategies (providing of information, education, and modelling) and structural strategies (infrastructure, pricing policies, and legal measures). The latter has usually been associated with behavioral intention rather than change, which makes it difficult to compare results.

Overall, promoting and establishing energy-saving behavior and sustainable energy consumption requires greater dissemination of information and practices (education and training) targeted to the population group (segmentation) using communication and marketing strategies, as well as focusing on regulation, legislation, and service provision. Enablement or encouragement of physical and psychological capability, as well as of physical opportunity can be operationalized through fiscal measures, regulation, legislation, and service provision. Finally, restriction and environmental restructuring are introduced as solutions to overcome physical opportunity. We recognize that restriction may be considered as neither acceptable nor practicable on a large scale. The BCW model recommends that intervention functions and policy categories should be assessed through the use of the APEASE criteria (affordability, practicability, cost-effectiveness, acceptability, side-effects/safety, equity) (Michie et al., 2014). However, in this present study, relevance of APEASE criteria is highlighted but not applied. In fact, adding the APEASE criteria would add a significant level of complexity to this research, once energy companies, regulators, consumers, and media would have to be interviewed, so that the feasibility of proposed interventions could be properly evaluated. In other words, since APEASE aims to choose which interventions should be prioritized (Michie et al., 2014), only the stakeholders mentioned above would be able to determine the acceptability, practicability, effectiveness, affordability, side-effects, and equity of each proposal. Thus, and based on its pertinence, this criterion should be properly applied in future research.

TABLE 3 BCW intervention functions and Policy Categories.

Intervention function	Definition	Policy categories	Example of intervention function
Education	Increasing knowledge or understanding	Communication and/or marketing, guidelines, regulation, legislation, and service provision	Publishing energy saving guidelines through media (traditional and social)
			Inclusion of energy efficiency at all levels of school curricula
Training	Imparting skills	Guidelines, fiscal measures, regulation, legislation, and service provision	Promotion of energy consumption practices in domestic environments, places of education, work, and public bodies, using for instance goal setting techniques
Restriction	Using rules to reduce the opportunity to engage in the target behavior (or to increase the target behavior by reducing the opportunity to engage in competing behaviors)	Guidelines, regulation, and legislation	Regulatory control of the validity and accuracy of household appliances energy labels
			Retailers' obligation to provide information regarding appliances' added annual cost for consumers at point of sale
Environmental restructuring	Changing the physical or social context	Guidelines, fiscal measures, regulation, legislation, environmental and/or social planning	Positive incentives and/or subsidies to make homes more efficient
			Promotion of tenders with the academic community and companies to promote new energy saving solutions
Enablement	Increasing means and/or reducing barriers to increasing capability (beyond education and training) or opportunity (beyond environmental restructuring)	Guidelines, fiscal measures, regulation, legislation, environmental and/or social planning, and service provision	Tax reductions on the purchase and continued use of efficient equipment
			Benefits for those who use efficient equipment (vouchers, discounts, protocols, etc.)

Source: Adapted from Michie et al. (2014).

In summary, the suggested policy categories can be broadly categorized as micro and macro-level. Macro-level factors include fiscal measures, regulation, and legislation, while micro-level factors range from those in an immediate, specific location: education and training, service provision, restriction, and environmental restructuring.

4 Discussion

Residential sector energy consumption is a pressing issue that requires urgent attention. The European Commission's "Energy Efficiency First Principle," prioritizes behavioral interventions to optimize energy use, reduce waste, and mitigate environmental impact. However, most public policy investment to date has focused on structural or technology-based strategies. Much remains to be done to reduce unnecessary household energy waste. This exploratory research aimed to deepen understanding of what behavior factors restrict Lisbon, Portugal residents from consuming energy more efficiently, and it has gone on to propose promising interventions.

Our findings suggest that both structural and especially behavioral strategies are necessary to improve efficient residential electricity consumption. According to our findings the main obstacles for efficient energy consumption are lack of capability (namely, physical), followed by opportunity (also physical). On the other hand, the absence of motivation (both reflective and automatic) is the least decisive factor in the adoption of energy-efficient consumption behavior. It was clear also that, regarding the (in)capability to adopt efficient energy consumption, the use of high consumption equipment (physical capability) and the lack of information or confusing information about energy expenditure (psychological capability) were the most frequently mentioned reasons. Within the physical opportunity field, poor home insulation and lack of financial resources to invest in energy solutions were the most frequently expressed opinions. Among the issues related to social opportunity, inefficient electricity consumption of other household members was the most prominent. This closely aligns with the fact that our data suggest that the motivation to adopt energy-efficient behaviors is inhibited by the lack of concern or forgetfulness about small gestures (automatic motivation) and the perceived lack of cost-effectiveness of change or a lack of environmental awareness (reflexive motivation).

Based on these findings and applying the BCW (Michie et al., 2014), we propose several interventions (each with specific policy categories), such as education, training, enablement, restriction, and environmental restructuring. We recognize that restriction may be considered as unacceptable or impracticable on a large scale, according to the APEASE criteria. It is worth mentioning that these interventions can act in a systemic way. Meaning, an intervention that acts on physical capability, for instance, can also contribute to physical opportunity.

Therefore, regarding the lack of physical capability, training (guidelines, fiscal measures, regulation, legislation, and service provision) and enablement (guidelines, fiscal measures, regulation, legislation, environmental and/or social planning, and service provision) appear to be the best solutions to overcome this restriction. To change small energy use habits, training is needed in addition to positive reinforcement and social influence.

Enablement could be achieved if Government incentives via through direct and indirect fiscal measures (e.g., tax reductions) might encourage equipment purchase.

Physical opportunity to efficient electricity use could be improved through enablement, environmental restructuring, training, and

restriction. Since lack of financial resources to invest in energy solutions was identified as a main constraint, the above-mentioned examples to enable physical capability (enablement) could also be used to promote physical opportunity: tax reductions or financial incentives (installment payments) to replace old and inefficient appliances. Environmental restructuring, on the other hand, could be achieved by positively incentivizing the building sector to adopt solutions contributing to rational electricity use by ensuring the thermal insulation, both in winter and summer (for example, adequate protection against heat in summer; the use of high thermal inertia materials to reduce temperature variations; taking advantage of sunlight in winter and the rational insulation of external surfaces to protect living spaces against unwanted heat exchange and condensation). Along this line, the link between university and industry could be further strengthened through competitions to encourage the presentation and adoption of environmentally friendly energy solutions. In other words, industry could challenge students and their educational institutions to rethink the current energy framework to provide new solutions to environmental energy issues, providing a conjoint effort positive to both parties. Additionally, to deal with the problem of poor thermal insulation, specific public policies could promote best practices of households, through training. This could take the form of official training visits organized at a Parish Council level. These training visits could also help identify financial solutions to invest in energy saving systems, as proposed by Boroni et al. (2012). Regarding macro-level policies, the government should improve the housing regulation framework. The goal would be to better monitor the insulation conditions of older houses for sale. This regulation change should help restricting the transaction of secondhand houses with poor insulation conditions (restriction).

Following the previous line of reasoning, psychological capability could be heightened by way of education (communication and/or marketing, guidelines, regulation, legislation, service provision), training (guidelines, fiscal measures, regulation, legislation, service provision) and enablement (guidelines, fiscal measures, regulation, legislation, environmental and/or social planning, service provision). These are relevant potential means to overcome the lack of information or confusing information about energy expenditure, the ignorance of the advantages of changing small gestures, the lack of training in sustainable energy consumption, the difficulty in finding energy solutions or excessive bureaucracy, the perceived inability to change, and the lack of knowledge in the use of electrical equipment. Focusing on education, we recommend an enhancement of advertising campaigns through media, with energy saving guidelines, as well as the diffusion of leaflets with tips for savings and/or efficiency. Inspired by Katsuki et al. (2023), Masanika et al. (2020), and Ukpe (2008) contributions regarding the health sector, we believe that leaflets can be an interesting communication tool: in conjunction with other strategies, they could help to increase awareness and knowledge issues. Looking more deeply into the education question, and taking into account the goals of sustainable consumption of the 2030 agenda of the United Nations, we recommend introducing didactic-pedagogical subjects and activities in school curricula, including training teachers at all levels of education about the principles that regulate the behavior of sustainable energy consumption, spreading this behavior through social influence across society, involving parents and families in this dissemination. These programs must necessarily go through kindergartens and primary schools, an idea very much in line with the visions of Koliopoulos and Constantinou (2012), Koliopoulos (2016), and Bächtold (2017) regarding the proximity between energy and school education. Public information campaigns by local authorities and NGOs must be emphasized to training consumers to adopting sustainable energy consumption by way of grants and funding for projects among different stakeholders.

Training can be solidified by the promotion of energy consumption practices in domestic environments, places of education, work, and public bodies, and this promises several benefits. The development of entrepreneurship and community projects in the energy sector, as deeply analyzed by Becker et al. (2017) and van der Horst (2008), demonstrate how models and businesses based on non-profit organizations or cooperatives (such as sharing-economies) might also help to enhance training aspects and transform energy into a true aggregating factor of social cohesion.

Enablement, in turn, highlights the increasing of means and the reduction of barriers to increasing capability (beyond education and training) or opportunity (beyond environmental restructuring). Based on this assumption, we recommend again the reduction of taxes on the purchase and continued use of efficient equipment, as well as the promotion of benefits for those who use efficient equipment (vouchers, discounts, protocols, etc.), which is very much in line with the information presented on the 'Guide to green innovation vouchers' from Europe INNOVA KIS-PIMS Project (Greenovate Europe E.E.I.G, 2011), which provided financial support for SME energy innovation.

It would also be necessary to investigate the legislation, government programs, educational initiatives, and awareness campaigns in Portugal to verify the degree of implementation of each of the proposed policies and their scope. Considering only the previously mentioned residential segment of the PPEC, a variety of measures, broken down into intangible (communication, education, auditing and training) and tangible (equipment, systems, resources) measures were instituted and which are aligned with those we propose. For instance: Information and dissemination measures that promote behaviors that allow more conscious decision making, with regard to the adoption of more efficient solutions in the consumption of electricity and/or gas; Efficient heating and cooling, including heat pumps, boilers, installation or replacement of more efficient air conditioning systems; Efficient lighting, including new light bulbs, digital control systems, use of motion detectors in building lighting systems; Food preparation and refrigeration with energy efficient systems; Other equipment and appliances aimed at reducing electricity consumption, e.g., new efficient devices, timers for optimal energy use, reduction of stand-by losses, low loss transformers; Energy efficient motors and drive systems; Fans; Solar panels for efficient heating (boilers and water heaters, heat pumps and solar thermal). Consumption management systems, including load management and power control systems. Information and awareness campaigns focused on promoting improved consumption efficiency; Studies on behaviors, practices or methodologies aimed at characterizing needs or identifying target audiences, sectors, equipment or processes for possible energy efficiency measures that promote the reduction energy poverty or improving energy efficiency in consumption.

This study makes several additional contributions. First, it contributes to environmental studies and practices by providing new evidence based on an innovative empirical approach applied to an empirical case. As far as we are aware, it is the first time that the

COM-B model has been applied to energy studies. Energy behavior (people's acts that lead to energy consumption) are under researched due to the lack of adequate approaches to address their complexity (Soares et al., 2017). The COM-B model allowed us to consider the complex nature of energy consumption addressing micro, meso, and macro factors.

Secondly, the BCW framework also brought another layer to these outputs. The proposed interventions not only answer Steg's (2008) alert to the need for and possible ways to reduce household energy use, motivating energy conservation; and enabling the adoption of relevant behaviors. These approaches are also fully aligned with the recommendations of the European Commission's "Energy Efficiency First Principle." Most national and international and national public investment aims to improve energy efficiency through actions or regulations that stress structural or technology-based strategies. However, without behavioral change these measures may not achieve their maximum potential (Steinberg et al., 2009). The proposed intervention framework represents our attempt to add value to society, combining scientific data with an analysis of national and international current energy policies, offering new perspectives to the energy consumption debate.

Thirdly, this research also contributes to the literature through the identification of a spectrum of different determinants that can be directly mapped onto the COM-B model and used to develop a measurement model. These determinants are aligned both with previous findings and underexplored ones (behavioral determinants). This is an important step which can help future models to have a more holistic perspective and predict (and change) the desired outcome, as well as understand the relative influence of each variable. This measurement model can thus display the relationship between the selected variables and can be examined for its goodness of fit.

All in all, with this article we provide empirical evidence of how energy consumption is a complex phenomenon, with different determinants or drivers and then present an innovative and holistic methodology that manages this complexity and integrates the behavioral approach.

5 Recommendations and limitations

This research intends to serve as an example for other researchers and policymakers to apply a new methodological approach (holistic and integrated) in the local assessment of energy consumption, as well as in the definition of appropriate responses, including the behavioral approach, in line with the latest European guidelines. Future research could also use these insights to test the effectiveness of the proposed interventions, which could then provide an empirical basis for sitting behavior policy implementation in the residential sector and in the workplace. We also recommend that companies and government institutions related to energy consumption enhance their communication strategies through a multidisciplinary approach, considering the public's capabilities, opportunities, and motivations, focusing overall on behavioral changes. It is also worth suggesting a deeper investigation into the legislation, government programs, educational initiatives and awareness campaigns in each European country (or in Portugal) to verify the degree of implementation of each of the proposed policies and their scope. To consumers, we recommend a continuous search for information, so that efficiency can be seen regarding costs, life quality, and the environment.

As to limitations, participants from our FG are a diverse sample in various demographic and social aspects, representative of the selected population, but they do not include all socioeconomic classes (notably upper-class A and lower-class D are lacking). Moreover, soon after the implementation of the FG, the theme "energy crisis" became a talking point in the media (due to the international economic and political context). We admit that this phenomenon may have affected participant attitudes regarding energy consumption. Also, we followed Pothitou et al. (2016) suggestion to conduct our research at the small-scale level, which means that our explanatory study is based on a small sample of households at local level, which limits the generalization of the results. Lastly, we only consider the energy consumption determinants in an urban living scenario. We admit that rural households and their lifestyles might reveal different outcomes.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The requirement of ethical approval was waived by Ana Margarida Barreto, NOVA University - FCSH, ICNOVA for the studies involving humans because Ana Margarida Barreto, NOVA University - FCSH, ICNOVA. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenef.2023.1250795/full#supplementary-material

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