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Loops, triangles, and transitions - Participatory Systems Mapping of energy poverty policies

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ABSTRACT

Current policy trajectories integrate energy poverty into decarbonisation policy agendas; the links between energy poverty, building efficiency, and energy prices justify this approach. Energy poverty, however, is a multidimensional condition which intersects several policy sectors. This paper employs a participatory systems mapping method to develop a Causal Loop Diagram depicting the Portuguese energy poverty system. Thirty-five participants were engaged in a multi-stage workshop to elicit expert perceptions of the main solutions and challenges for local-scale energy poverty mitigation in Portugal. The results revealed key narratives that inform relevant policy approaches framing energy poverty within broader decarbonisation policies. These narratives exposed involuntary energy restriction behaviours and raised concerns about increased energy demand due to climate change. Citizen-led alternative energy models and building renovation were viewed as key solutions to energy poverty. Despite this, the social mechanisms which promoted citizen participation, including trust and energy literacy, were perceived as generally positive, with little emphasis on their potential limitations, suggesting a reduced focus on the social-behavioural aspects of participation. Discussions during the workshop revealed a lack of consensus among Portuguese stakeholders regarding current and future energy needs in the country. Additionally, the results exposed low engagement with the issue of energy disconnections at both the policy and civil society levels. The conclusions present policy and research recommendations for Portugal, centred on promoting inclusive approaches to citizen participation in energy transition activities.

1. Introduction

In the European Union (EU), framing energy poverty (EP) within broader goals to decarbonise the energy supply has become common practice in recent years. EP is generally understood as insufficient access to energy services [1]. Initially the causes of EP were attributed to a combination of three factors (income, energy price and energy efficiency), the so-called “triangle”. However, more recent framings acknowledge that EP is a multidimensional condition which can be caused by several factors, including building efficiency and low household income levels, and can negatively impact health and educational outcomes [2–4]. Thus, mitigating EP presents natural synergies with policies addressing different dimensions of the EP problem, namely policies such as the Renovation Wave [5], which simultaneously adhere to broader decarbonisation goals and target the building efficiency dimension of EP via energy retrofits and thermal comfort improvements. The Action Plan for Affordable Energy [6] (prioritising decarbonisation

of the energy supply as a tool to reduce energy costs), addresses both the affordability dimensions of EP and contributes to decarbonisation targets. Overarching decarbonisation initiatives such as the European Green Deal [7] mitigate social dimensions of EP, through, for example, potential job creation for the energy poor [8].

In addition to being a multi-dimensional problem, EP is also a multi-scalar issue, and therefore involves multiple stakeholders [9]. Household scale specificities, including culture, household demographics, physical building characteristics, and geographical location [4,10] as well as socio-political influences [11,12] can influence experiences of EP and the ability to take advantage of mitigatory policies. Therefore, no “one size fits all” approach to EP can be consistently applied across the European context.

In response to the need for tailored approaches, initiatives such as the European Energy Poverty Advisory Hub (EPAH), which supports local European governments in implementing decarbonisation and energy poverty mitigation strategies [13], have emerged. However,

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challenges remain in designing synergistic approaches to decarbonisation and EP policies that do not “leave anyone behind”. For example, in Spain, citizen awareness and education levels are potential barriers to the uptake of energy communities [14]. In the UK, low digital literacy and resource limitations associated with smaller “grassroots” retrofit schemes pose challenges to EP mitigation efforts [15].

In pan-European studies, southern Europe has consistently been identified as a region with high levels of EP. Specifically, according to consensual indicator data, the percentage of households in Portugal, Spain, and Greece unable to maintain adequate warmth exceeds the EU average of 9 % at 15.7 %, 17.6 %, and 19 %, respectively (2024 data) [16]. The zone is also characterised by high vulnerability to climate change (CC) [17] and comparatively low incomes [18]. Within the southern European context, Portugal has distinguished itself as an energy transition frontrunner, being one of the first countries in the world to set carbon neutrality targets for 2050 and phasing out coal-fired generation in 2021 [19]. On the other hand, the Portuguese EP strategy estimates that between 1.8 and 3 million people suffer from the condition in Portugal, with 660,000 in severe EP [20]. Previous works in Portugal have highlighted a challenging institutional setting for alternative energy models (which should theoretically mitigate EP), favouring larger and well-established energy companies [21] and expressing concerns regarding the availability of funding for retrofit activities (both at the citizen and governance levels) [4,22].

Alternative energy models encourage greater levels of citizen participation than traditional energy models [23], where citizens have a greater level of involvement in the production, sharing and selling of energy [24]. Indeed, under the auspices of delivering a just transition, in current decarbonisation policy trajectories, citizens are identified as a key stakeholder group whose responsibilities are mainly seen as making “informed” decisions regarding energy and implementing behaviour change at the individual level [24]. The mitigation of EP is another tenet of just transition delivery [7], yet those in EP generally have less ability to make informed choices. For example, groups who do not own their properties (such as students and tenants who are frequently identified as vulnerable to EP [25,26]) are unlikely to be able to produce or sell energy. Hence, the agency of citizens to participate in energy transitions depends on the relevant social context.

Thus, while Portugal has achieved impressive progress from a decarbonisation perspective, the benefits of the energy transition at the local scale, and for the energy-poor (who typically have reduced investment capacity), are limited. Instead, as a multi-dimensional condition, EP is part of a wider system, where a dynamic series of interrelated social, economic, and technical factors influence the success of mitigatory policies. Identifying the main elements of this system according to the perceptions of different stakeholders and understanding the causal interactions between them is crucial for gaining insights into the root causes of policy success or failure and highlighting leverage points for effective policy intervention.

The previous paragraphs demonstrate the severity of the EP situation in Portugal, emphasising the need to develop new insights to support the development of effective mitigatory strategies. EP is a multidimensional condition; therefore, problem diagnosis and mitigatory strategies should involve a broad range of stakeholders. Consequently, to map the EP system, a method which elicits and reflects the range of perspectives implied by this diverse stakeholder profile is required.

Systems thinking approaches frame reality in terms of dynamics and relationships [27], Participatory Systems Mapping, a systems thinking modelling approach, is suitable for facilitating the representation of complex system features in a concise and understandable format [28]. A system can be considered a group of parts with varying degrees of interrelation, and which collectively form a whole (a system) with a particular purpose. In providing an overview of these parts and the dynamics of their inter-relations, systems thinking generates insights into how to manipulate the system for improved outcomes [27]. In PSM modelling approaches, different stakeholders are asked to collaboratively develop

Causal Loop Diagrams (CLDs) [29,30]. CLDs (also referred to as system maps) are a specific type of model representation used in system dynamics approaches which allow the depiction of feedback loops within a system.

In energy research, participatory modelling approaches are advantageous due to their capacity to deal with complexity [15,31], their ability to account for both technical and non-technical aspects, and to generate insights into the underlying stakeholder perceptions and motivations that determine system behaviour [24,31]. A review of contemporary literature reveals few studies that apply systems thinking in EP research. Studies specifically employing PSM include Hale et al. [9], who apply a participatory behavioural systems mapping approach to the challenge of decarbonising homes in Wales, touching on fuel poverty but not taking a specific focus on this element. In 2021, Barbrook-Johnson & Penn [28] explored UK policies that affect the “energy trilemma”, namely the provision of secure, sustainable, and affordable energy, to test the utility of systems mapping in policy evaluation processes. Research utilising systems thinking in the EP field includes Papada et al. [33], who employed fuzzy cognitive maps with the aim of capturing the complexity of EP in a holistic manner, and Che et al. [34], who employ CLDs to illustrate feedback loops in the EP system in China. In the latter case, however, this method is used as a precursor to further quantitative methodologies and thus has a reduced emphasis on the participatory element of the analysis.

Taking the above into account, this study applies a Participatory System Mapping (PSM) approach to capture a systemic perspective articulating the dynamics of the EP system to support policy implementation. By applying this method, this study intends to reveal a co-constructed vision of the multi-dimensional problem of EP in Portugal and to identify key leverage points for EP mitigation. The process engaged different stakeholders [35] to elaborate on the system behind policy problems [32], rather than viewing problems in isolation. The Causal Loop Diagram translates the structure of the Portuguese EP system, identifying the interrelations between different variables and their causal relations.

This paper aims to answer two main research questions: 1. How do stakeholders perceive the Portuguese EP system, and what are the main system variables, dynamics, and leverage points? 2. What are the main solutions and challenges for local-scale energy poverty mitigation in Portugal implied by the main system narratives and policy pathways in the EP system?

The innovative contributions of this paper are twofold; firstly, it presents a novel application of a PSM approach in the EP field, offering a deeper understanding of the structure behind the system. Secondly, the paper contributes to the identified knowledge gaps specific to the Portuguese case. Finally, given that fellow southern European countries share similar socioeconomic and climatic characteristics with Portugal, the results of this paper are potentially relevant in the wider southern European setting.

The article structure is as follows: the Methods are presented in Section 2, and the Results and discussions (Section 3) outline the causal relationships and policy pathways in the Portuguese EP system. Section 4 concludes by offering research and policy recommendations based on the results.

2. Method

The following sections give more detail on the Portuguese case study (Section 2.1) and provide detailed descriptions of the PSM method employed in this paper (Sections 2.2–2.4). PSM has been recommended in energy transition and decarbonisation research focused on stakeholder engagement [28] and policy-decision-making scenarios involving multiple actors in building stock decarbonisation activities [9]. Thus, linking back to the multidimensional characteristics of EP across scales, time, and geographies, as well as the chain of actors involved in diagnosing and mitigating the condition (as outlined in the

Introduction), we consider PSM an appropriate and innovative method to explore.

Correspondingly, to develop systemic insights into stakeholder perspectives on EP, a PSM approach was implemented. This involved three distinct sequential phases in accordance with Lopes & Videira [36], each entailing an associated set of activities (as shown in Fig. 1) and described below. These are the a) Pre-workshop phase, b) the PSM workshop exploring local-scale solutions to EP in Portugal, involving stakeholders in the building of participatory CLDs, and c) a post-production phase. We replicated and adapted techniques commonly used in the sustainability and environmental fields (for example, sustainable consumption, ecosystem services, and sustainable tourism) [29,36,37], as there are limited studies focused on participatory modelling in EP.

2.1. Case study

In recent years, the research and policy focus on EP in Portugal has intensified. Contemporary research in the EP field in Portugal has revealed greater vulnerability to the condition in the north and central regions of the country [4], the need for significant investment in renovation activities [22], and the benefits and drawbacks of framing energy poverty within broader decarbonisation policies [38,39].

Alongside increased research interest in EP, national political focus on this issue has also ramped up, with the first official energy poverty strategy published in 2024 [20], setting a series of targets for 2050, such as reducing the percentage of the population living in households unable to maintain adequate heat to <1 % in 2050. In 2024, the Portuguese National Observatory of Energy Poverty was also approved, aiming to monitor the progress of EP in Portugal and contribute to ongoing public policy development [40]. Other linked policies that frame EP mitigation in Portugal within wider decarbonisation pathways include the Long-Term Strategy for the Renovation of Buildings [41], the Roadmap for Carbon Neutrality [42], and the National Energy and Climate Action Plan [43].

While increased interest in this issue in Portugal is encouraging, EP is still a pervasive problem. Critically, as a low-income country, Portugal faces significant financial challenges which impede the ability to invest in energy efficiency at both the citizen and state levels [22], styming the progress of technical EP solutions. These financial constraints overlap with social elements of the energy transition, including citizen's perceptions of agency, where 45 % of respondents to the Eurobarometer survey define climate change as a serious problem but the percentage of respondents (28 %) believing they are personally responsible for climate

change has decreased (-15 % compared to 2021) amid recent economic turbulence [44]. In this sense, although there are several obvious multi-sectoral challenges relevant to EP in Portugal, a systemic perspective that articulates the main elements of the system and their interactions is lacking. Consequently, this paper explores a PSM approach to map the Portuguese EP system from the perspective of national stakeholders.

Applying a PSM approach to map the EP system has several potential advantages. Firstly, EP is a multidimensional condition; therefore, the capacity of PSM to capture multiple stakeholder views, rather than individual perspectives (where ultimately effective policy actions require collaboration between multiple actors), is highly appealing. Secondly, the ability of PSM to represent complexity is useful for articulating stakeholder perceptions of cause/effect dynamics. Thirdly, gaining a deeper perspective into the underlying structure of the EP system could enhance understandings of how the different multi-dimensional drivers and consequences of EP interact. Lastly, energy research and decarbonisation policy pathways have frequently been criticised for being overly technical and undervaluing the social dimensions of transitions [45]; hence, the ability of participatory mapping to represent the dynamics of the technical and non-technical factors of the EP system is particularly apt. In this sense, testing a PSM approach for EP analysis is a useful and timely contribution as EU Member States endeavour to implement just and inclusive energy transitions at speed. The following subsections outline the key activities involved in applying the PSM method.

2.2. Pre-workshop Phase

The pre-workshop phase (Fig. 1), consisted of three sub-steps, described subsequently. The workshop phase was preceded by two significant background activities that set the stage for the research presented in this paper. Both activities focused on the degree of integration of EP into decarbonisation policy in Portugal. The results of these research activities, alongside the results presented in this paper, serve to triangulate our findings and provide methodological robustness, where a policy analysis of the links between EP and decarbonisation policy in the Portuguese case set the political context as per Mahoney et al. [39]. A series of semi-structured interviews (undertaken in [38]) highlighted diverse perspectives in relation to the interlinkages of climate change, energy transition and EP agendas in Portugal, exposing areas of agreement and discord between stakeholders. Informed by these two studies, the PSM workshop and corresponding analysis facilitated the representation of the Portuguese EP system in a single CLD diagram.

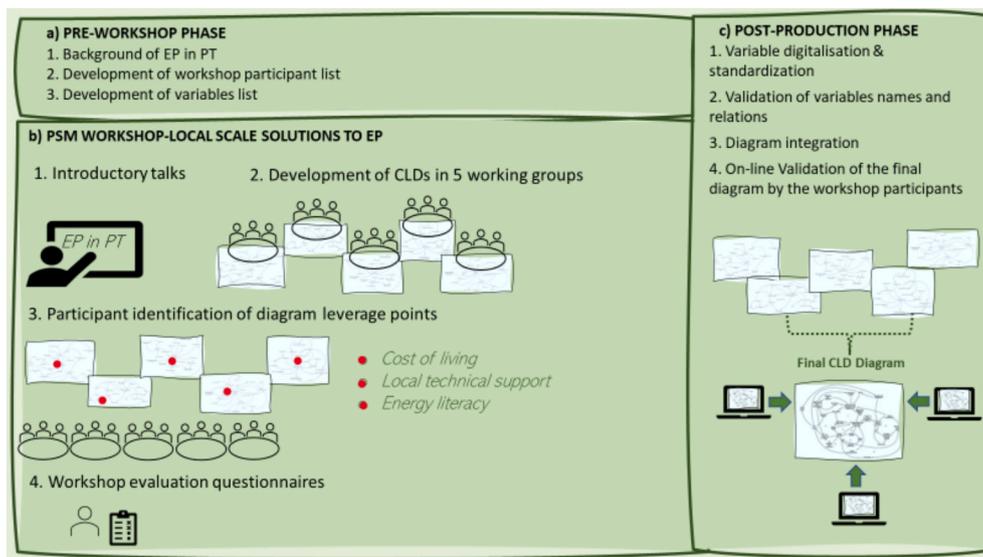


Fig. 1. PSM Workshop method schematic.

Step 1 Background of EP in Portugal-research into the background of EP in Portugal, supported by Mahoney et al. [38] and Mahoney et al. [39] (as above).

Step 2 Development of a workshop participant list- where preceding scoping activities undertaken in the aforementioned studies provided insights into the policy landscape, relevant stakeholder groups and their corresponding interests and influences. Such scoping activities are recommended by Lopes & Videira [29], Hale et al. [9], and Rossade et al. [31]; in the former two instances, both policy review and stakeholder engagement activities are encouraged. The workshop participants consisted of key stakeholders in the Portuguese EP system (full breakdown shown in Table 1), operating at different scales (from the national to the local) and with a wide range of expertise (from consumer protection to civil engineering), representing divergent disciplinary perspectives which are highly relevant for exploring the multidimensional nature of EP. Thus, despite the skew towards the “University/Research” category, the mapping activity and following roundup talks resulted in a well-balanced discussion. Furthermore, the views of energy-poor households were represented by consumer organisations, NGOs, and local associations, as these groups have considerable first-hand experience of working with the energy poor.

Step 3 Development of variables list - for use during the conceptualisation phase of the workshop, serving as a prompt for participants if necessary (informed once again by [38,39]).

2.3. Participatory Systems Mapping workshop on local-scale solutions to energy poverty

The workshop was held as a national activity by the Energy Poverty Advisory Hub. EPAH is the leading European initiative aimed at supporting EP mitigation at the local scale [13], hence the focus on local solutions. The co-construction of CLDs is particularly valuable in its capacity to provide insights into the dynamic nature of the relationships between different elements in the system, some of which remain relatively undefined in Portugal, as the country is in the early stages of policy engagement with EP. The workshop consisted of four steps:

Step 1 Introductory talks-providing an introduction to the Portuguese case study, which included talks from workshop participants involved in different areas of EP in Portugal. The talks focused on themes of governance, energy efficiency, financing programmes, community energy, and local-level citizen support.

Step 2 Development of CLDs in five working groups-CLDs, also known as system maps, are a specific type of model representation used in systems dynamics approaches [37,46,47] and allow the identification of feedback processes through the use of variables (labels used to describe the various elements in a system, e.g., income and living costs). Arrows in the diagram represent the causal links (the direction of the relationship) between two variables, and the type of relationship (positive or negative) is represented by a “+” in the case of a positive relationship and a “-“in the case of a negative relationship. A series of links can form feedback loops, categorised as reinforcing or balancing [47]. Where a reinforcing loop maintains change in the same direction and a balancing loop counteracts change, generally loops with an uneven number of “-“s are labelled as balancing and loops with an even number

Table 1
Number of workshop participants by organisational type.

Organisation Type	Number of participants
Energy & Environment Agency	5
Cooperative	1
NGO & Associations	6
University/Research	14
Media	1
Consumer Organisation	1
Governmental	7
Total	35

of “-“s are labelled as reinforcing [29].

During the collaborative workshop, the participants were split into five working groups and asked to develop a CLD, translating their mental models of the EP system to identify local-scale solutions to EP in Portugal.

To develop the CLDs, each working group was assigned a “driver” of energy poverty to focus on as the starting point for mapping the problem. These drivers were income, energy efficiency and energy price, which are recognised as elemental drivers of energy poverty [48,49]. There were two working groups focused on energy efficiency and income, and one on energy prices. Participants were oriented with a leading question, which aligned participants' perceptions towards a common goal and created a shared baseline for generating comparable diagrams [36]. Each working group was asked to map the EP system based on the driver assigned to them. In the process of developing the systems map, participants were asked to consider how local solutions could contribute to mitigating EP.

The outputs of the working group activities were five separate CLDs, one for each group (Fig. 1). Workshop participants were asked to give a brief presentation of the resulting diagram from each group, allowing them to share their process for creating the diagram and highlight the main discussion points.

Step 3 Participant identification of diagram leverage points-participants were asked to mark “leverage points” on the CLDs constructed by the other groups. Participants circulated through the different groups to mark the leverage points, allowing them to reflect on the different variables and connections. Leverage points are defined by Kim [27] as “An area where a small change can yield a large improvement” pg.19. The leverage points identified during the workshop are elaborated on further in Section 3.

Step 4 Workshop evaluation questionnaires-workshop participants were asked to fill out a questionnaire evaluating the workshop. To conclude this phase, a round-up discussion summarised contemporary knowledge on the research topic and described the process for developing a unified diagram based on the workshop outputs.

2.4. Post-production phase

The final part of the PSM process was the post-production phase, consisting of four editing tasks. These tasks, adapted from [29,36], are outlined in (Fig. 1) (section c), which describes the four steps undertaken in the postproduction process. The research team undertook the first three steps to produce an integrated diagram that could be shared with workshop participants for validation via an online questionnaire (step 4). The results of all four steps were combined to produce the final CLD. These steps are summarised briefly below:

Step 1 Variable digitalisation and standardization-digitalisation of the variables from the workshop versions of the CLDs into a common file. A standardisation process was followed, which involved a thorough revision of all variables and a cross-comparison of these variables across the five diagrams. This cross-comparison allowed for the removal of duplicates. At this stage, intermediate variables were developed where necessary; these reflected concepts expressed in the CLDs, which were then further adapted for suitable use in the integrated diagram (next steps).

Step 2 Validation of variable labels and relationships-the interrelation of system variables and the polarity of relationships were validated in accordance with the workshop diagrams. Each of the five diagrams was checked for any missing relationships between variables; the polarity of relationships was added in cases where it had been omitted from the original version. Any repetitive variable labels were merged. At this stage, we also created digital copies of the CLDs. A check was made for feedback loops in the diagrams.

Step 3 Diagram integration -having digitalised the variables and verified the causal links, we integrated the five CLDs into one. This phase began by integrating all the variables and their corresponding

relationships into a single diagram. Drawing on the core structures of the EP systems represented in each of the individual diagrams, this integrated version was adapted to create a clear and meaningful representation of the ideas expressed in the workshop. To simplify the diagram, repetitive ideas were merged, and adaptations of the variables were cross-checked against the originals. This phase was complete only when a version of the diagram that accurately represented the concepts articulated in the five original versions had been developed. This was achieved through the internal revision of several iterations of the diagram by the research team.

Step 4. Validation of the diagram by workshop participants - The integrated diagram was then shared with the workshop participants, who were asked a series of questions regarding the final version of the diagram, including their opinions on the variables and relationships represented. In total, ten responses were received to the workshop validation questionnaire. The questionnaire consisted of a set of ranked responses (summarised in Fig. 2) and open-ended questions. The ranked responses indicate that overall, the participants agreed that the diagram represents the Portuguese EP system (with no participants selecting the “disagree” options). The results of the open-ended questions were analysed and resulted in minor adaptations to the final diagram (described in the following section).

2.4.1. Loop narratives

The combined results of the post-production phase contributed to the development of a series of “loop narratives” described in Section 3.1 (Figs. 4–8). These narratives emerged iteratively through reflection on the key themes articulated in the workshop and the translation of these themes into variables and causal relationships during the post-production stages. For example, the narrative “Cost of living causing bill arrears and reduced thermal comfort; bill arrears as a driver of vulnerability” combined relationships identified by different working groups describing causalities between the cost of living, debt, and thermal comfort with the distinct but linked relationships between thermal comfort and health and quality of life, where poorer health ultimately leads to greater vulnerability. The development of the loop narratives facilitated a deeper reflection on overarching themes that bridged these narratives, revealing two main pathways representing the perceived solutions to the various problems within the system, according to the workshop participants. These pathways are outlined and

evaluated in Section 3.2. For example, the pathway “Energy restriction and building renovation” is derived from loop narratives that link energy consumption and human well-being and combines these with narratives proposing building renovation as a tool to address both energy restriction and climate change problems. Unpacking the solution pathways in this way provided an opportunity to comment on the dynamics of the proposed solutions. It also promoted the exploration of generally under-recognized topics in Portugal, such as energy disconnections (discussed in later sections).

3. Results and discussion

Fig. 3 presents the unified CLD following the postproduction process described in the Methods section, outlining the causal relationships in the Portuguese EP system as perceived by our workshop participants. The figure legend describes the various diagram symbols, explaining how to differentiate between positive and negative causal relationships, the representation of time delays and system leverage points and the significance of the different colours used to label the reinforcing (“R”) and balancing (“B”) loops. The CLD also reveals how the workshop participants viewed local solutions to EP. Despite the focus on the local scale, the EP system, as perceived by workshop participants, included broader national or international variables, e.g., “Legislation and regulation”. This highlights that the multi-dimensional nature of EP renders it subject to influences on a larger scale; for instance, “Energy prices” are influenced by “External dependency”.

A full list of the variables presented in the diagram, along with their corresponding descriptions, is provided in Annex 1. A comparison of the variables identified in the diagram shows a reasonable degree of overlap with works scoping out the breadth of topics linked to EP. For example, in their exploration of existing and missing links between EP and other scholarly debates, Stojilovska et al. [50] identify climate change, national economic conditions, energy efficiency, and the quality of buildings. Similarly, concepts included in Papada et al’s [33] fuzzy cognitive mapping analysis of energy poverty in Greece include energy consumption, arrears on energy bills, and education. Variables such as “Professional training” and “Bureaucracy” appear more specific to the Portuguese case. Papada et al. [33] also observed similarities and differences between topics identified in their participatory activity and those identified in other contexts. On the one hand, this demonstrates

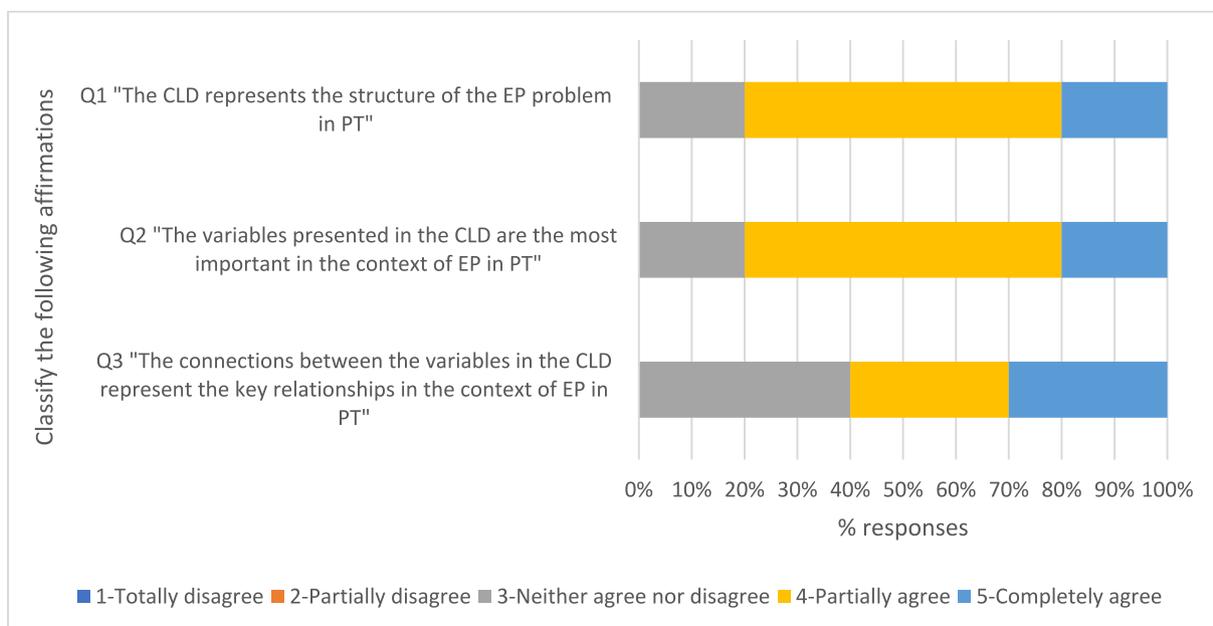


Fig. 2. Responses to the diagram validation questionnaire.

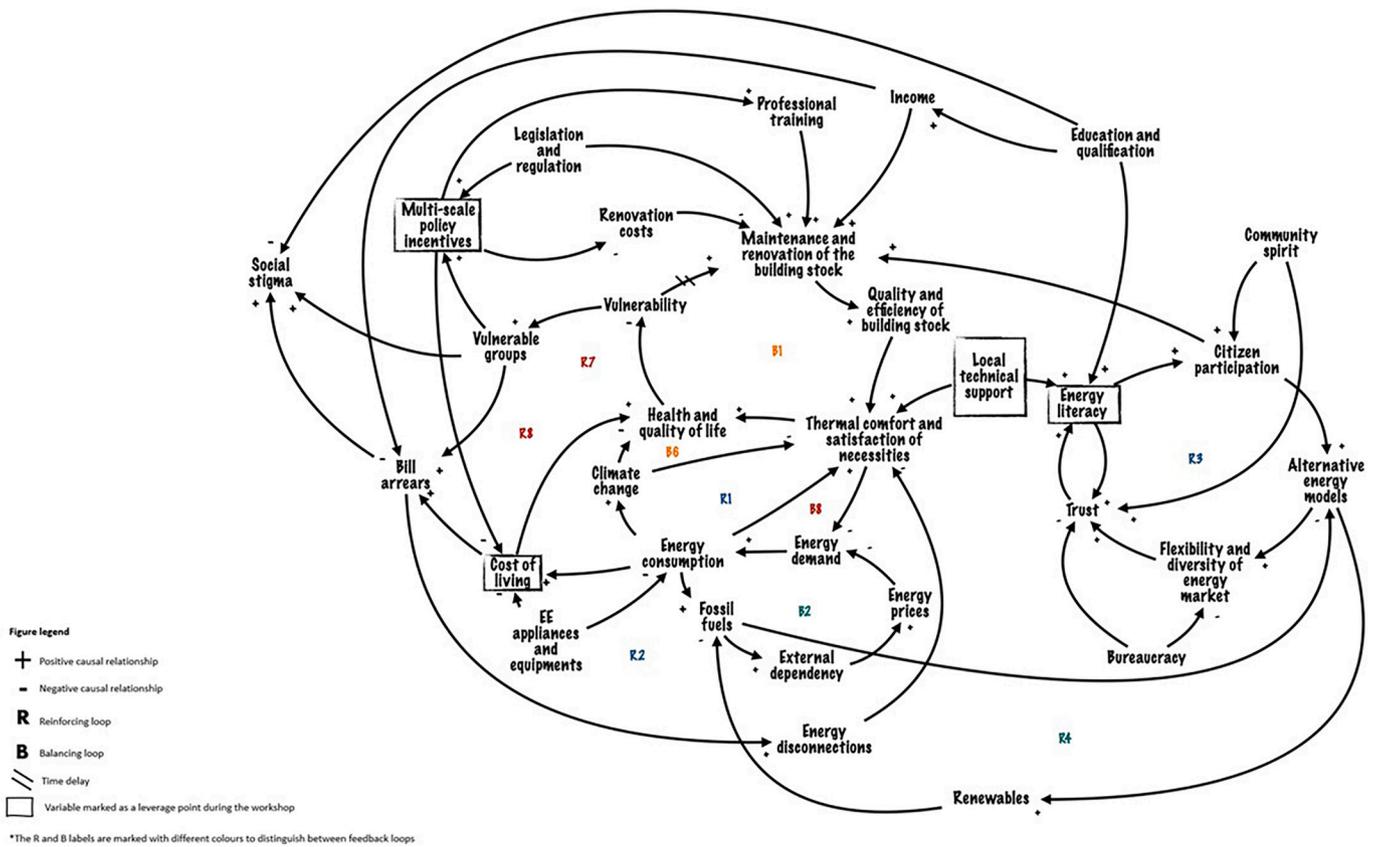


Fig. 3. Integrated CLD representing the Portuguese energy poverty system (leverage points marked in squares).

the benefits of applying a PSM approach to shed light on unique case-specificities; on the other hand, it implies that the workshop findings cannot be directly generalised.

Bureaucratic processes in energy community establishment have been problematic in Portugal [21]. While it is challenging to locate detailed statistics on the Portuguese retrofit market, official monitoring activities such as the Portuguese Long-term Renovation Strategy [41] identify the need to rapidly increase the renovation rate [22], which in turn represents a growing need for skilled professionals [51,52]. Linked to the dearth of skilled workers in Portugal is a sustained trend of youth emigration [53]. In a global evaluation of inequities in energy access, Avik et al. [54] find that low-skilled workers are potentially those most at risk of being superseded by technological advancement. Thus, where lower-skilled workers are less likely to be in demand abroad, the rapid advancement of skills development is particularly important in Portugal.

In addition to the variables, the diagram reveals several balancing and reinforcing loops representing essential dynamics in the Portuguese EP system. The reinforcing and balancing loops labelled (“R” and “B”) correspondingly in the diagram uncover a set of critical narratives depicting systemic patterns relevant to the resolution of EP (loops B1, B6, R3), as well as some systemic challenges to the realisation of this aim (loops R1, R2, R4, R7). The following sections present these loops and their corresponding narratives. The CLD progresses existing knowledge on EP in Portugal by providing a full visual representation of the EP system. Previous authors had focused on issues such as energy efficiency and building retrofit [4,22], alternative energy models [21], and social factors [55], yet an articulation of the EP system and its corresponding dynamics was lacking. Interestingly, while the workshop explored local solutions to EP and indeed uncovered some local solutions, e.g., “Local technical support,” the CLD presented a set of multi-scale variables, partly explained by Portugal’s centralised governance structure but also reflecting the influences of EU policy and international interdependencies. The participants, however, viewed local-scale

solutions as integral to the mitigation of EP and particularly advocated for accessible, tailored energy efficiency advice at the local scale (reflected in the variable “Local scale technical support”).

At the conclusion of the workshop, participants were asked to identify variables they perceived as leverage points in the system and to complete an evaluation questionnaire. These leverage points are outlined in the diagram; the workshop evaluation results are presented at the end of this section. Finally, as described in the Methods section, the unified CLD was shared with workshop participants for verification.

3.1. Loop narratives

Drawing on the loops presented in the final CLD and the iterative process described in the Methods, the following sections detail the key narratives depicted in Figs. 4–8. It is important to note that all relations represented should be read according to the rule of *ceteris paribus*, translated as “as all other things being equal”, meaning that the relationship between two variables should be viewed in isolation.

3.1.1. Building renovation as the primary response to energy poverty and climate change (B1 & B6)

Loops B1 and B6 (Fig. 4) both illustrate this relationship, where in the case of B1 “Vulnerability” acts (after a delay) as a driver of increased “Maintenance & renovation of the building stock” to increase “Quality & efficiency of building stock”, this improves “Thermal comfort and satisfaction of necessities” which positively affects “Health & quality of life”, thus reducing “Vulnerability”, illustrating the positive impacts of renovation on energy poverty. The additional benefits which occur as a result of renovation are shown in B6, where “Thermal comfort and satisfaction of necessities” drives “Energy demand”, increasing “Energy consumption”, leading to intensified “Climate change”, which reduces “Health & quality of life”, this increases “Vulnerability”, which (as in B1) drives, “Maintenance & renovation of the building stock”, and, assuming

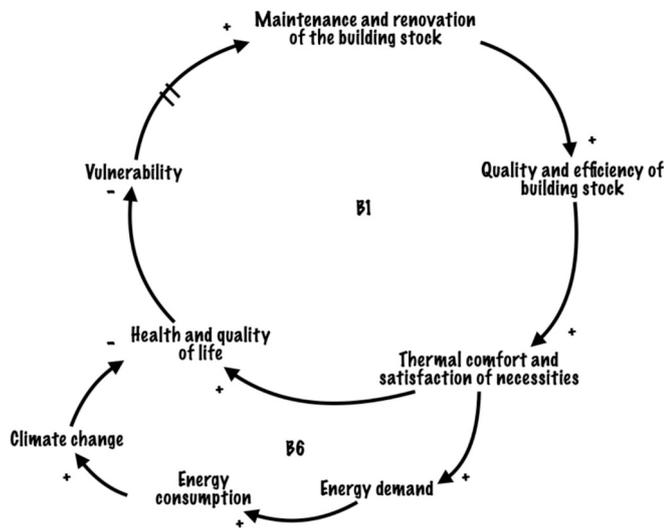


Fig. 4. Loops B1 & B6 renovation as response to EP & CC.

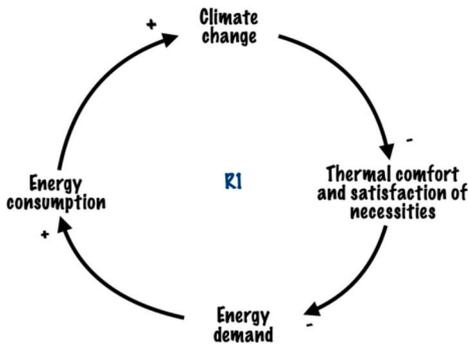


Fig. 5. Loop R1, CC impacts on thermal comfort & energy consumption.

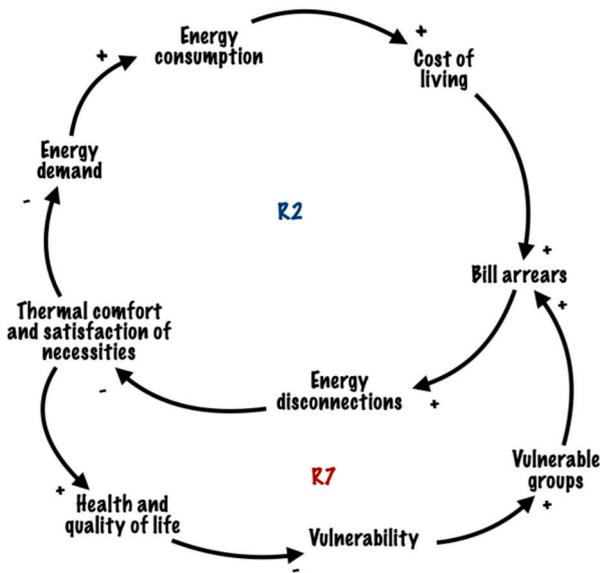


Fig. 6. Loops R2 & R7 costs, bill arrears, reduced thermal comfort & vulnerability.

all other variables are constant, mitigates the impacts of climate change and EP simultaneously. These loops confirm current policy trajectories that encourage building renovation and energy efficiency measures [5,42,43], indicating the alignment of the workshop participants (important stakeholders in the Portuguese EP system) with this

trajectory.

3.1.2. Climate change as a driver of reduced thermal comfort and increased energy consumption (R1)

Loop R1 (Fig. 5) highlights the threat “Climate change” poses to “Thermal comfort and satisfaction of necessities” where the worse the effects of “Climate change” the lower the levels of “Thermal comfort and satisfaction of necessities”, where considering all other variables to be constant, higher “Thermal comfort and satisfaction of necessities” reduces “Energy demand” and higher “Energy demand” increases “Energy consumption”, ultimately more “Energy consumption” results in more severe “Climate change” impacts. Notably, this loop is relevant to works such as [4,56], which highlight threats to the Portuguese decarbonisation strategy due to the thermal comfort gap in Portugal and the amount of energy required to bridge it. R1 thus exposes challenges for EP and climate change policy agendas.

3.1.3. Cost of living causing bill arrears and reduced thermal comfort; bill arrears as a driver of vulnerability (R2, R7)

The reinforcing R2 (Fig. 6) loop shows how “Bill arrears” contribute to reduced “Thermal comfort & satisfaction of necessities”, where the higher the “Cost of living”, the greater the level of “Bill arrears” and the more “Energy disconnections”, this reduces “Thermal comfort and satisfaction of necessities”, which (where all other variables are equal) reduces “Energy demand”, lessening “Energy consumption”. R2 also reveals a negative causal relationship between “Energy disconnections” and “Thermal comfort and satisfaction of necessities”, underscoring the connection between energy and human well-being [57]. Loop R7 illustrates how “Bill arrears” lead to more “Energy disconnections”, the more “Energy disconnections”, the less “Thermal comfort and satisfaction of necessities” the better the level of “Health & quality of life”, with better health comes less “Vulnerability”, where increased “Vulnerability” leads to more “Vulnerable groups” and more likelihood of “Bill arrears”. Although not part of the loop, the diagram also shows that the more “Vulnerable groups”, the more “Social stigma” (a relationship suggested in the workshop validation exercise).

Thus, loop R7 adds the dimension of compromises to “Health & quality of life” due to “Energy disconnections”. These loops are problematic from an EP perspective, but as they imply reduced energy consumption, they are not problematic from a climate change perspective.

3.1.4. Energy prices as a limit on energy consumption, energy consumption as a provider of thermal comfort (B2, B8)

In loop B2 (Fig. 7), “Energy prices” increase as a result of a higher level of “External dependency”, which is a consequence of reliance on “Fossil fuels”; the higher the “Energy prices”, the less “Energy demand” and thus less “Energy consumption”. Tying into the links between human well-being and energy use, B8 adds the dimension of lower “Thermal comfort and satisfaction of necessities” as a consequence of reduced “Energy consumption”, where more “Energy consumption” enhances “Thermal comfort and satisfaction of necessities”, the more “Thermal comfort and satisfaction of necessities” (with all other variables remaining equal) the less “Energy demand”. These tie into loops B1 & B6 in that if “Thermal comfort and satisfaction of necessities” can be achieved without the use of fossil fuels, the outcome is positive for both climate change and EP; loops B2 & B8 present a scenario where consumers are forced into energy restriction, where once again this energy restriction is detrimental to the EP agenda but not the climate change agenda.

3.1.5. Citizen participation as a driver of alternative energy models and a more flexible energy market, fossil fuels as a threat to the uptake of alternative energy models and renewable energy (R3, R4)

R3 (Fig. 7) presents a solution from an EP perspective where the higher the level of “Citizen participation” the more significant the

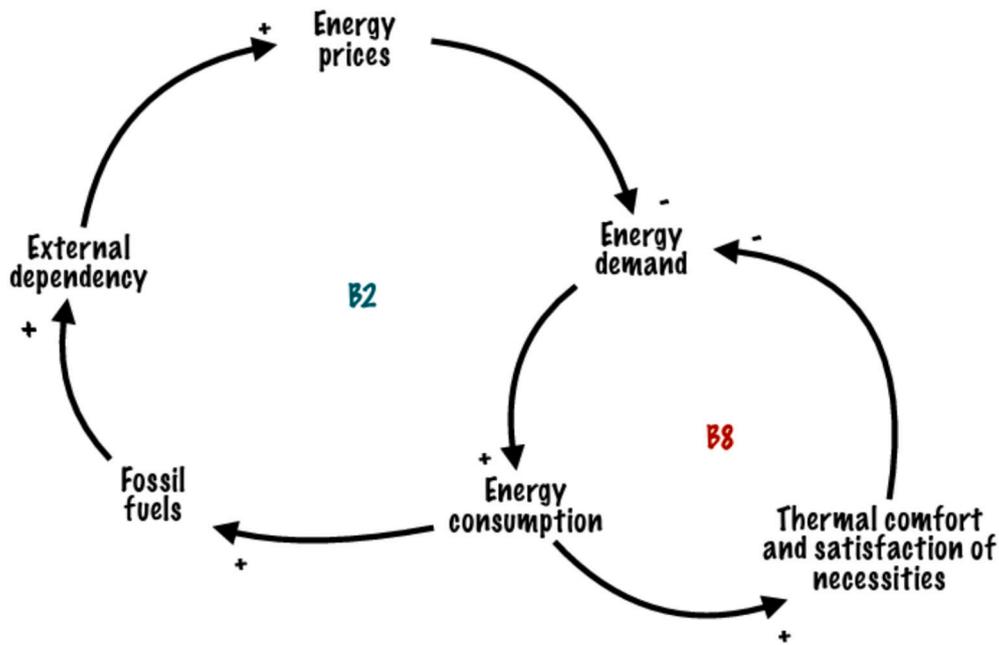


Fig. 7. Energy prices, energy consumption & thermal comfort.

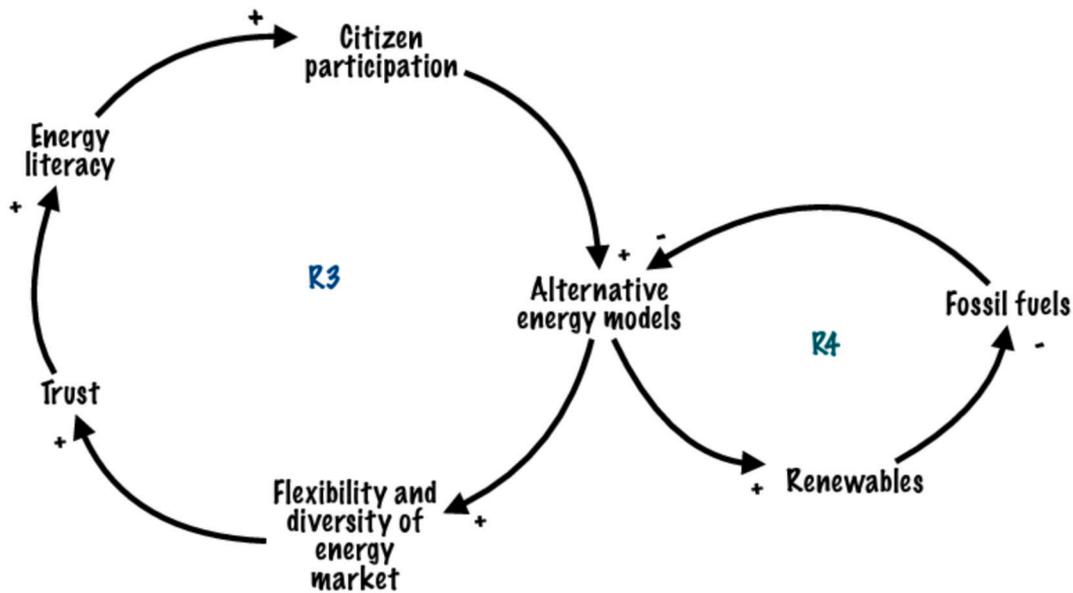


Fig. 8. Loops R3 & R4 citizen participation, alternative energy models & fossil fuels.

uptake of “Alternative energy models”, and more “Alternative energy models” increase “Flexibility and diversity of energy market”, a more flexible and diverse market (where consumers are not locked into limited choices of large incumbent suppliers) increases levels of “Trust” and correspondingly “Energy literacy” which drives more “Citizen participation”. This loop reflects workshop participants’ perceptions of citizen participation and the contribution of “Alternative energy models” to resolving EP. Interestingly, while not part of R3, the variable “Community spirit” drives both “Citizen participation” and “Trust”, highlighting that “Alternative energy models” are contingent on a set of social drivers.

In contrast, loop R4 represents a challenge to EP mitigation, in this case, “Fossil fuels”, where all other variables are equal, reduce the uptake of “Alternative energy models”, which promote the uptake of “Renewables” and consequently reduce reliance on “Fossil fuels”. In this

sense, while the continued presence of “Fossil fuels” presents a threat to the uptake of “Alternative energy models”, the loop also shows how to mitigate this problem, namely by increasing the uptake of “Renewables”.

Despite being beneficial to EP mitigation, R3 is not directly beneficial for the climate change agenda. However, the pathway in R4 indicates a synergistic solution for both scenarios, according to our workshop participants, i.e., renewable-based alternative energy models.

The previous sections describe the main reinforcing and balancing loops presented in Fig. 3. However, several variables shown in the diagram do not form part of the loops but are important influences on the system. Examples include “Legislation and regulation”, “Education and qualification”, “Income”, “Social stigma”, and “Community spirit”, where the latter was added following the workshop validation activity. In this case, “Legislation and regulation” implies top-down pressure

(either at the National or EU level) driving “Multi-scalar policy incentives” which encourage “Professional training” (where participants perceived that in Portugal, a lack of skilled professionals to undertake retrofit work is problematic). “Professional training” drives “Maintenance and renovation of the building stock”, which forms an integral part of loops B1 & B6 described above. Both “Multi-scalar policy incentives” and “Cost of living” were identified as leverage points by our participants. “Multi-scalar policy incentives” reduce the “Cost of living”, which also forms part of loop R2 and has a significant influence on “Bill arrears”. “Multi-scalar policy incentives” also reduce “Renovation costs”, driving increased “Maintenance and renovation of the building stock”. “Community spirit” impacts both “Citizen participation” and “Trust”, which ultimately impact the acceptance of energy transition solutions such as “Alternative energy models” and “Maintenance and renovation of the building stock”.

3.2. System complexity and possible pathways

Overall, the causal loops identified in Fig. 3 reveal a series of potential solutions and challenges relevant to EP mitigation as perceived by the workshop participants. The causal loops uncovered narratives related to the energy restriction behaviours resulting from energy affordability challenges and drivers of vulnerability (B2, R2, R7), the challenge that climate change poses to future energy needs (R1), the links between energy consumption and human well-being (R2, R7, B2, B8), and citizen-led solutions to EP (R3). Interestingly, the loops presented conflicts between EP, climate change, and energy transition goals, which are significant in the current policy framing of EP under broader decarbonisation targets. A deeper reflection on these narratives (as described in the Methods section) led to the identification of two overarching pathways exposed by the diagram; the first pathway we identified was “Energy restriction and building renovation solutions”, and the second was “Participatory solutions”. The following subsections explore the significance of these pathways.

3.2.1. Energy restriction and building renovation

An important policy goal conflict between EP and efforts to mitigate climate change arises in the context of involuntary energy consumption restrictions referred to in loops B2, R2, and R7. In these loops, energy consumption restriction is imposed by higher “Energy prices” and “Bill arrears”, with the most severe impact in the latter case being “Energy disconnections”. These loops set the scene for deeper reflection on themes of energy restriction and disconnections in Portugal.

In the Portuguese case, low levels of self-reported thermal comfort contrast with relatively low rates of bill arrears. This low rate of bill arrears is attributed to restrictive energy behaviours [58,59], which, to some extent, reduce the risk of energy disconnections. Dedicated literature on energy disconnections in the Portuguese case is sparse. However, an analysis of the recently published Portuguese EP strategy reveals 524,143 energy supply interruptions due to failure to pay bills on time in 2019. Reasons for non-bill payment are not known, yet consumers in the lowest national earnings bracket, with average earnings of 6608 € a year/550 € a month, spent 14 % of their income on energy expenditure compared to 10 % in the 10,365 € a year / 864 € a month income bracket [20].

The above suggests that individuals in the lower income bracket are more likely to allocate a higher proportion of their income to energy costs in Portugal, with corresponding impacts on bill arrears and the likelihood of experiencing energy disconnections. In recent years, activist movements and the research community have raised concerns about the adverse effects of disconnections. For example, Hesselman [60] finds that energy disconnections impact several human rights, including housing, health, and education rights. Formed in 2017, the Right to Energy Coalition campaigns for a “right to energy” in European legislation, implying a ban on disconnections [61]. These efforts have begun to yield results, with a provisional agreement protecting the

vulnerable and energy-poor from disconnections reached by the European Council and the European Parliament in December 2023 as part of broader electricity market reforms.

Such progress is undoubtedly encouraging, with the provisional agreement stating, “Member States shall ensure that vulnerable and energy-poor customers are fully protected from electricity disconnections by taking the appropriate measures, including the prohibition of disconnections or other equivalent actions.” pg.5 [59].

In Portugal, due to the described energy restriction practices, accurately accounting for the scale of vulnerability to EP presents a challenge, where damaging coping strategies have been identified [5] and concerns about “underconsumption” of energy have been raised [62]. Definitions of vulnerability and EP in the Portuguese Energy Poverty Strategy are translated as follows:

Vulnerable consumer: “Domestic energy consumers who find themselves in a situation of economic deprivation and or social need and potentially in a situation of energy poverty” pg.98 [20].

Energy poverty: “A household’s lack of access to essential energy services where these services provide basic levels of dignity and health, namely heating, hot water, cooling, sufficient lighting and the energy necessary for running appliances, taking into account the national context, social policy and other relevant national policies, caused by a combination of factors, including at least, the lack of affordability (of energy prices), insufficient income, high energy costs and poor energy efficiency of buildings.” pg.73 [20] which is based on the EU definition set on the latest energy efficiency directive.

Comparing these strategy excerpts reveals that those categorised as vulnerable are not, by default, those defined as energy-poor. This recognition of vulnerability, in addition to EP, is necessary given the uncertainties surrounding the accurate assessment of EP in Portugal [55,62]. Critically, however, in the Portuguese case, the reason for disconnections is unknown [20]. Without explicit knowledge of the cause of disconnections, it is difficult to predict to what extent the EU provisional ban will protect consumers, particularly those who must be categorised as “vulnerable” or “energy poor” to benefit. Therefore, understanding the underlying causes of disconnections is an essential next step in achieving the desired level of consumer protection in Portugal.

Moreover, while efforts to ban disconnections for the energy poor and the vulnerable are undoubtedly commendable, the diagram reveals that vulnerability is not the only pathway to disconnection, with “Cost of living” identified as the other cause. In Portugal, between 2021 and 2022, the inflation rate increased from 1.3 % to 7.8 % [63], with average costs for weekly food shopping rising from €184 in February 2022 to €229 in February 2023 [64]. These cost increases emphasise the increased financial difficulties Portuguese households face. Critically, disconnection affects not just the bill payer but all household members, including children, where a review of the EP strategy does not reveal any direct reference to protecting children from disconnections [20]. González-Pijuan et al. [65] state that children suffer physical, mental, and educational impacts due to energy disconnections. Each of these impacts has a distinct moral dimension and, from an energy justice perspective, crosses into the area of recognition justice (on the basis that children are a vulnerable group) [66]. Impacts on education and corresponding implications for later employment opportunities also have links to energy justice and sustainability framings, which emphasise the importance of not harming future generations [67].

3.2.2. Themes

of energy-restrictive behaviour also tie into causal relationships between energy consumption and thermal comfort (shown in loop B8). This ultimately represents the relationship between human well-being and energy consumption, where energy plays a fundamental role in determining the quality of life [57]. This dynamic lies at the crux of policy conflicts arising between the goals of mitigating EP and achieving carbon neutrality by 2050. Existing policy approaches to EP mitigation on the pathway to decarbonisation seek to achieve thermal comfort

through more efficient buildings and renewable energy sources, providing essential needs without compromising climate change goals [5,7]. In Portugal and Europe, climate targets are now enshrined in law [68,69]; simultaneously, policy requirements for EP mitigation are becoming more stringent. These increasingly tight policy requirements explain limited accounting for increases in energy consumption in Portuguese decarbonisation policies [38] and justify the pathways to EP solutions via “Maintenance & renovation of the building stock” presented in loops B1 and B6. These findings, in turn, lend support to current drives for decarbonising Portugal’s building stock [41].

Renovating the building stock is challenging, given the prevalence of poor building quality, the high costs associated with it [22], and the lack of official statistics on the renovation rate [41]. Recent partially subsidised energy efficiency programmes have shown high adherence rates, suggesting increased public interest in renovation [70]. The importance of renovating the building stock cannot be understated and aligns with current policy approaches; however, it is important to balance renovation activities with social and behavioural solutions, as energy use has a distinctly social dimension [71]. Additionally, research shows that environmental concerns have a stronger influence on decisions related to reducing energy use than financial concerns [72], demonstrating the potential of encouraging more efficient practices among citizens rather than overlooking the groups that must undergo the transition [45].

Effective behaviour changes and corresponding reductions in energy consumption are crucial for mitigating the challenges climate change poses to achieving thermal comfort (as per loop B6). The “Climate change” variable exacerbates the challenge of ensuring sufficient energy provision for thermal comfort, as climate change is expected to have negative impacts on achieving thermal comfort. However, uncertainties regarding its exact manifestation make it challenging to predict future domestic energy requirements [56].

Future concerns about thermal comfort are more broadly applicable in Europe, with climate change causing increasing temperature extremes and residential energy consumption trends correlating with the number of Heating Degree Days (HDD) and Cooling degree days (CDD) (days when theoretically heating or cooling would be required), i.e., generally when the extremes of heat and cold are greater more energy is consumed [73]. The number of CDDs in 2050 is expected to increase significantly, additionally, predicted temperatures will more regularly exceed the thresholds recommended for comfort and health [74].

The preceding discussion details themes of energy consumption, achieving thermal comfort, and building renovation, revealing that the diagram presents two routes to reducing energy consumption. These routes are either through involuntary restrictive behaviours or through building renovation activities. With the variables of “Renovation costs” and “Income” linked to “Maintenance and renovation of the building stock”, a level of social division in access to renovation measures is suggested. Another motivator of building renovation is “Vulnerability”, which eventually stimulates renovation as a mitigatory policy response. A practical example of vulnerability incentivising change in Portugal is the “Efficiency voucher”, a funding stream dedicated to energy efficiency measures for the energy poor, implemented as part of the COVID recovery package [75]. While ultimately effective, this pathway implies that suffering serves as a motivator of change, which clashes with policy ideals of a “just transition.”

3.2.3. Participatory solutions pathways

Loop R3 presents a bottom-up solution where citizens drive the uptake of “Alternative energy models”, combined with the links between “Alternative energy models” and “Renewables” (loop R4). These loops present a synergistic solution for EP and climate change objectives. Presently, in Portugal, “Alternative energy models” (including energy cooperatives and communities) represent a limited market share [21] and can be considered an unknown quantity in terms of EP mitigatory

capacity. Such models generally aim to provide fairer conditions for energy consumers [23] and can result in lower energy costs [74]. That said, evidence suggests accessibility limitations for marginalised groups [76,77], where supportive policy conditions are needed to ensure increased levels of prosumerism do not push up costs for non-prosumers [80].

In Portugal, the EP strategy emphasises the need to remove barriers for citizens participating in energy communities, with funding schemes for residential energy communities and collective auto consumption activities [20]. This is an encouraging move; however, Scharnigg & Sareen [78] find a mixed profile of actors involved in alternative energy models in Portugal. These actors include the renewable energy divisions of existing energy incumbents; the authors also highlight greater trust in non-profit institutions versus organisations with vested financial interests. During the workshop, however, participants viewed “Alternative energy models” with active citizen involvement as a powerful tool for mitigating EP, where variables of “Energy literacy” and “Trust” were essential elements of this process.

The contributions of “Citizen participation” to “Alternative energy models” are significant in the current policy scenario. The fundamental role of citizens in the energy transition underpins both European and Portuguese policy approaches [3,48,49]. Policy rhetoric often includes narratives of citizens taking ownership of the transition and greater choices regarding energy suppliers. Despite this, research spanning France, Ireland, Italy, Spain, and the UK has shown that citizens can feel “locked out” and disconnected from energy system decision-making processes [79]. Similarly, linking back to “Alternative energy models” in Germany, Vogel et al. [80] identify barriers that prevent women from participating in energy communities. Considering the developmental stage of alternative energy models in Portugal, a more nuanced understanding of the facilitators and barriers to inclusion would be valuable for the case.

The CLD shows that “Citizen participation” drives the uptake of “Alternative energy models” and, in turn, greater “Flexibility & diversity of energy market”, where actions linked with citizen participation include adopting renewable energy technologies, membership in energy communities, and participation in political decision-making [81]. Regarding energy citizenship, Beauchamp & Walsh [82] highlight that citizenship involves greater consumer rights and responsibilities. Correspondingly, we argue that consumers must perceive they are receiving their rights to feel motivated to assume responsibility. Linking back to the arguments of Lennon et al. [79] and connecting these with loops describing forced energy restriction practices, we suggest that the groups affected by these conditions in Portugal will potentially consider themselves disempowered and thus less incentivised to participate in the transition. This ties into broader questions about the true meaning of citizen participation and who it benefits [83].

Like “Alternative energy models,” the variables “Energy literacy” and “Trust” (identified in loop R3) can be considered concepts that warrant deeper investigation and understanding to maximise their potential and establish their limitations. In 2019, Martins et al. [84] investigated energy literacy among Portuguese university members, including students and technicians, finding the energy literacy level to be “moderate”. Later, the work of Martins et al. [85] finds high levels of energy literacy but lower levels of financial knowledge in the Portuguese university community.

Comparison of two general assessments of energy literacy in Portugal (held respectively in 2020 and 2024) which characterised energy literacy on a scale of 1–100 (with 100 implying a total knowledge of all study areas linked to energy literacy and no knowledge of these study areas) show a marginal increase in energy literacy over the four-year period, increasing from an average score of 42,8 points in 2020 to 45,3 points in 2025 [86,87].

In Fig. 3, the causal relationship between “Education &

qualification” and “Energy literacy” is shown; this link is substantiated by Mills & Schleich [88], who find that higher education levels are associated with the adoption of energy-efficient technology and energy conservation behaviours. Our workshop participants viewed energy literacy as a means of enhancing citizens' capacity to make informed energy decisions, increasing their likelihood to want to participate in energy transition activities, and ultimately to adopt alternative energy models. This perspective did not account for any limiting factors on the benefits of energy literacy, e.g., improved energy literacy cannot completely overcome investment barriers for very low-income groups. This reflection is also absent from the Portuguese EP strategy [20]. Furthermore, while valuable studies in Portugal explore literacy in university students, staff [85] and attitudes to climate change (which also encapsulate energy literacy) [89], there is limited research at the citizen level exploring how energy literacy influences the capacity to mitigate EP. Thus, understandings of how energy literacy intersects with EP alleviation are somewhat superficial and require further exploration and qualification to maximise the potential of this tool.

Literature exploring EP and trust in the Portuguese context is also limited. However, Großmann et al. [90] found that poor transparency in the energy billing process contributed to consumer mistrust in the country. There was also a general distrust of politicians and state institutions due to abuses of power. In Fig. 2, “Trust” is increased by “Flexibility and diversity of energy market” and “Community spirit”. Trust has a reinforcing relationship with “Energy literacy”; “Bureaucracy” decreases “Trust”. Thus, the variables the participants associated with trust were not entirely consistent with those identified in the literature. “Trust” is not explicitly mentioned in the Portuguese EP strategy, nor is it linked to relevant EP alleviation measures, such as energy literacy and citizen energy spaces, outlined in the strategy [20]. Additionally, in the section of the CLD focused on the dynamics of building renovation (B1 & B6), the loops are more detailed than loop R3 (highlighting participatory solutions), suggesting that the participants' mental models are more focused on building renovation and correspondingly on financial and technical measures rather than social solutions.

These incomplete articulations of the relationships between trust, energy literacy, and citizen participation suggest that stakeholders have an oversimplified view of the social mechanisms driving participation in Portugal. Therefore, a deeper exploration of the nuances of these tools is essential to establish who they help and how, as well as any relevant limitations to their capacity, in order to avoid overshadowing social and behavioural solutions. This is particularly important, as these solutions are more accessible and affordable than measures such as retrofitting and energy efficiency upgrades.

Fig. 2 represents the main threat to the uptake of “Alternative energy models” as the continued presence of fossil fuels (shown in loop R4), where loop B2 shows the main driver of fossil fuel use as increased “Energy consumption”. As stated previously, “Renewables” are the primary tool identified in the integrated CLD to reduce fossil fuel reliance. The dynamic revealed in R4 is not an insignificant consideration in Portugal, which, despite receiving international praise for the speed at which it has integrated renewables [19], still has some way to go in reducing fossil fuel reliance. In 2021, natural gas and petroleum fuel sources represented 24 % and 41 % of primary energy consumption, respectively. Additionally, while external dependency in Portugal is following a downward trend, in 2021, total primary energy consumption from external fossil fuel sources stood at 67 % [91].

A key mitigation measure addressing EP in Portugal is the social energy tariff. With 768,196 people in receipt of the social electricity tariff and 57,206 in receipt of the social gas tariff [92]. With such high levels of tariff adherence and government statistics in Portugal suggesting that EP affects between 1.8 and 3 million people [20], the

removal of the tariff seems unlikely. Despite this, the tariff (in the case of natural gas and partially in that of electricity) funds the use of fossil fuels, undermining efforts to achieve carbon neutrality and representing another policy goal conflict between mitigating EP and addressing climate change.

3.3. Workshop roundup discussion and leverage points

In a roundup discussion at the end of the workshop, participants showed a lack of agreement regarding whether it was necessary to increase energy consumption to resolve EP. This connects with ongoing debates about what constitutes a sufficient level of energy to achieve a decent living standard, where interpretations of “decent” and the corresponding amount of energy required to achieve it vary between different countries, cultures, and households [12,93]. Another dimension of this discussion was that the Portuguese climate is generally mild. Therefore, homes did not require the same level of renovation to achieve thermal comfort as other European countries with greater temperature extremes. This lack of consensus on this crucial point is potentially problematic for the current policy trajectory, as stakeholder perceptions can significantly impact the feasibility of future policy options [94]. This theme also reinforces the urgency of profiling the energy needs of Portuguese consumers, as discussed in the previous section.

The participants also identified leverage points outlined (in squares) in the integrated CLD (Fig. 3). Notably, each leverage point identified an area over which Governments can exert influence, e.g., social support to reduce the “Cost of living”. Identifying “Energy literacy” as a leverage point adds weight to earlier arguments for further research in the Portuguese case. Notably, these leverage points are not necessarily those with several connections (usually the more influential variables), suggesting that there may be more leverage points than those marked in the diagram. Despite this, the leverage points identified in the workshop were considered the most important by the participants, suggesting that acting on them could lead to system change.

Workshop participants strongly emphasised the provision of local support, attested by marking “Local technical support” as a leverage point; this emphasis can be explained by the workshop's exploration of local EP solutions. In this context, however, the participants emphasised the importance of more robust consumer support and engagement. Drawing on these results and the analysis of the CLD, a series of policy and research recommendations are presented in the Conclusions.

Finally, with increased policy emphasis on EP in Portugal, running the event as an EPAH activity had the advantage that the participants were familiar with this leading EU initiative on energy poverty and willing to engage with events within its scope.

3.4. Workshop evaluation

In the interest of transparency and good practice, an evaluation process was conducted at the end of the workshop. Fig. 9 presents the results of this evaluation, where participants were asked nine questions regarding their satisfaction with the workshop on a scale of 1–5, revealing a generally high level of satisfaction among participants. The participants were also asked to evaluate the organisation of the workshop; 72 % of participants rated the workshop as “very organised”, “and 28% as “organised”. Finally, the participants were asked if the workshop was a worthwhile use of their time, 97 % participants selected “yes”, “3 %” selected “to some degree”. The generally high level of participant satisfaction is a positive reflection on the workshop, with one participant noting that the workshop was a valuable opportunity to gather EP practitioners in Portugal and to incentivise discussion between them.

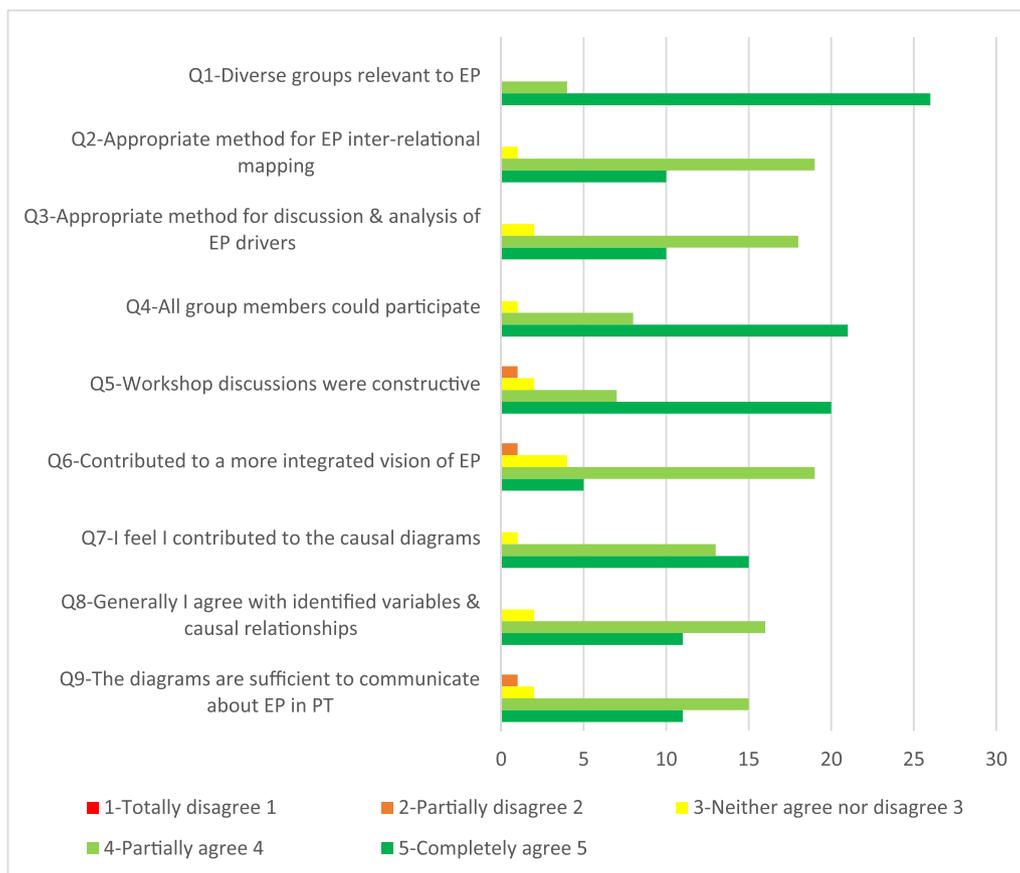


Fig. 9. Results of the workshop evaluation questionnaire.

4. Conclusions and policy implications

Over the years, previous authors have shed light on the complex web of policy debates and structural factors that either cause, are caused by, or exacerbate EP, or occasionally, a combination of all three. These valuable contributions have expanded contemporary understandings of EP, emphasising its multidimensionality. Yet, a systemic exploration of the cause/effect relationships in the EP system was lacking, particularly in southern Europe. With early iterations of EP and related decarbonisation policies underway in Portugal, the results presented in this paper are an innovative contribution to the field. Additionally, the integrated CLD, which presents an overview of the Portuguese EP system according to the stakeholders engaged in the workshop, is a tangible visual aid for national and regional policy actors. The visualisation of the EP system also meets the research aims set out at the beginning of the paper.

The unified CLD highlights solutions and challenges to mitigating EP in Portugal and sheds new light on previously under explored topics in Portugal. In this sense, PSM complemented rather than contradicted traditional EP analysis techniques. Namely, quantitative approaches can provide insights into the proportion of the population affected by EP, and econometric techniques reveal statistical relationships. PSM, however, exposes the mental models informing policy responses.

The main solutions for EP mitigation were identified as building maintenance and renovation, and citizen-led alternative renewable energy systems. Challenges included uncertainties regarding the actual energy needs of Portuguese energy users and potential increases in energy needs as a result of climate change. The analysis revealed several new insights for the Portuguese case, including an under-recognition of the adverse impacts of energy disconnections and a limited understanding of the social mechanisms encouraging citizen participation. Despite the workshop's focus on local-scale solutions, many of the

proposed actions apply across multiple scales. That said, the participants expressed a high regard for the value of local-scale approaches.

In generating the insights elaborated above, the application of a PSM process to elaborate the structure behind the Portuguese EP system proved a suitable and effective tool for providing a deeper understanding of EP in the country. Notwithstanding the benefits of the PSM method, the final diagram represents only the views of those engaged in the process and is not all-encompassing. It is, therefore, important to combine these outcomes with alternative methods that may add new dimensions to the results presented herein. This is particularly important as EP in the EU cannot be fully represented or indeed mitigated by a single method, indicator, or stakeholder group; instead, collaborative action across diverse sectors and disciplines is required.

Drawing on the valuable insights gained from the CLD and corresponding analysis, the following sections present a set of recommendations for policy and provide final remarks, limitations, and suggestions for future research.

4.1. Policy recommendations

The following recommendations are based on discussions held during the workshop and highlight important action areas for policy actors in the Portuguese EP agenda. The recommendations are also generally informative for agents operating in the southern European and EU contexts.

1. Provide support and advice for citizens on energy issues via representatives of local authorities and energy agencies - To facilitate participation both in alternative energy models and in the uptake of energy efficiency measures, citizens require targeted social and technical support from so-called "trusted agents" (often those operating at the local scale). This support will sometimes entail presential step-by-

step support through funding applications, e.g., energy efficiency programmes, where these trusted agents can assume essential mediator roles between private enterprises and citizens. Currently, local organisations in Portugal face significant resource challenges [95]; therefore, the first step is to engage with this stakeholder group to understand their capacity to enact these mediator roles. It is also important to understand any regional variations in capacity and to provide adequate support to local organisations with reduced access to resources.

2. Promote research into energy literacy and trust- Our study identified energy literacy and consumer trust as key drivers behind alternative energy models. However, current understandings of what motivates consumer trust in Portugal are limited. Additionally, recent evaluations of energy literacy levels in Portugal do not include any reference to EP or any exploration of the relationship between increasing energy literacy and reducing EP [87]. This could be achieved through citizen engagement activities, including interviews, surveys, and focus groups, generating insights into the potential and limits of these social behavioural solutions, which, if leveraged effectively, can be made accessible to a wide group of citizens.

3. Provide tailored guidance for citizens making energy consumption choices in the home and selecting domestic equipment -This extends to helping citizens understand the cost-benefit dynamics of investments in energy efficiency measures. Relevant approaches include so-called One Stop Shops (both digital and physical), where citizens can receive individual, tailored advice from energy and home renovation experts. The relevance of this recommendation is supported by the creation of a network of fifty “energy spaces” by the Portuguese government, which are physical drop-in centres where householders can receive tailored energy advice [96].

4. Maintain up-to-date statistics on energy disconnections and investigate their underlying causes - Further investigation is needed into the reasons for energy disconnections; updated public disconnection statistics are also crucial. This is particularly urgent given the severe adverse impacts of disconnections on both vulnerable and energy poor households.

4.2. Final remarks, limitations, and recommendations for future research

In outlining and evaluating the various pathways in the diagram, this paper presents the advantages and disadvantages of the current policy approach, providing insights for policy actors in Portuguese decarbonisation agendas. Portugal shares key geographic and socio-economic characteristics with its southern European neighbours (for example, hot summers and a strong potential for the development of the solar energy sector); thus, the research findings and policy recommendations presented are also relevant to other countries in the region. In representing not only the dynamic relationships which enable or exclude citizens from the benefits of energy transitions (e.g., energy literacy facilitating participation in alternative energy systems), this research contributes to ongoing discussions in European academic and policy discourse centred on the delivery of inclusive transition processes and the systemic patterns driving citizen inclusion or exclusion.

The CLD underscores the relationship between energy consumption and human well-being, which contemporary policy approaches aim to address through energy efficiency measures and the adoption of renewable energy [97]. Despite these trade-offs, the diagram highlights the interdependencies between EP and climate change, centred on the balance between sufficient energy use and reducing greenhouse gas emissions. These findings support current policy approaches for incorporating EP into the broader carbon neutrality agenda in both Portuguese and European contexts. Therefore, the diagram reveals alignment between the perspectives of the stakeholders engaged in the workshop and the current policy trajectory on these two significant points. This alignment is important, considering that the workshop participants are key stakeholders in the Portuguese EP system.

These alignments with the current policy approach are encouraging;

however, our explorations of participatory solutions and energy restriction behaviours reveal various social inequities that generally affect consumers with lower incomes, lower education and qualification levels, or a combination of both. We also reveal some uncertainties regarding these solutions, including a reduced exploration of concepts of trust and energy literacy in Portugal, which were perceived as significant influences on citizen participation. This overlapped with one-dimensional articulations of these concepts during the workshop, the main goal of which was to capture and depict the structure of the Portuguese EP system from the participants' perspective.

To overcome these uncertainties, further research should be undertaken at the citizen level to explore the extent to which stakeholders view EP as a technocratic rather than a social and behavioural issue. Ethnographic research focused on energy use practices at the local scale in Portugal indicates significant variations in citizens' interests, knowledge levels, and the types of energy saving practices they employ (if any). Despite exhibiting divergent degrees of engagement with energy saving, many citizens faced common barriers, principally limited investment capacity and slow bureaucratic processes, which impeded access to domestic energy efficiency improvements [98]. These findings pave the way for future citizen-level research, which may shed light on the diverse needs of different profiles of EP consumers, as the diagram did not provide detailed insights into the heterogeneity of those classified as energy poor.

Another significant “unknown” was exposed by the participants' lack of consensus regarding whether energy consumption in Portugal needs to increase to mitigate EP. This argument underscores the need for a deeper understanding of the energy needs of the Portuguese population, which is currently complicated by citizens adopting coping strategies for heating and cooling, as well as patterns of underconsumption and/or hidden energy poverty. This issue also applies outside Portugal in the European setting, where the emphasis on principles such as “energy efficiency first” attempts to mitigate both EP and GHG emissions increases.

Key limitations of this research pertain to the transferability of the workshop results, discussed in previous sections. A further limitation is that in its present form, the CLD is a static representation of the EP system; thus, an interesting avenue of future research would be to explore how to transform the CLD into a system dynamics model that facilitates the testing and evaluation of different policy scenarios.

Future research should also investigate the motivations and limits on citizen participation to better understand how to involve citizens in specific activities (such as alternative energy models), which can have positive effects both on EP and on wider decarbonisation targets. This is particularly relevant for vulnerable citizens who are often excluded from such activities. This research should engage with stakeholders from a broader range of organisational types in the EP sector, and critically with citizen groups.

This paper reveals a reduced policy focus on addressing potential needs for increased energy consumption among vulnerable populations in Portugal. This policy gap also applies at the EU level, where detailed datasets on the energy needs of Member State populations are lacking. Thus, an important area of future research is a thorough evaluation of these needs in different European geographical and socio-economic contexts.

To conclude, this paper draws on participatory inputs to produce a CLD depicting the EP system in Portugal, a country in the early phases of implementing EP mitigation policies and developing a dedicated EP stakeholder ecosystem. Exploring the causal relationships between the variables, many of which overlap with policy debates related to EP in the literature, advances existing knowledge in the field. By evaluating the interactions of EP solutions presented in the loops with linked policy agendas (such as climate change), the paper reveals that these solutions are not always fully synergistic for all agendas. Nonetheless, it also highlights a high level of interdependency between these agendas, which supports the current policy framing. Finally, the policy

recommendations provide a crucial basis for enhancing citizen participation in the Portuguese case, promoting equitable access to the EP solutions.

CRedit authorship contribution statement

Katherine Mahoney: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Rita Lopes:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Investigation, Conceptualization. **João Pedro Gouveia:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Annex 1-Variable description table.

Variable name	Description (short summary of how the workshop participants expressed the meaning of the variable).
Alternative energy models	Renewables based energy models. These systems were understood to imply lower energy costs for consumers and more inclusive ownership structures (including prosumer models)
Bill arrears	Delays in consumer energy bill payments (often due to a lack of funds to make these payments)
Bureaucracy	Complex governmental administrative processes which consumers struggle to navigate
Citizen participation	The involvement of citizens in energy transition activities, namely participation in alternative energy systems such as community energy models
Climate change	Shifts in global weather and climate patterns driven by the impacts of human activities
Community spirit	A shared sense of community between citizens, promoting group activities which positively benefit the local area
Cost of living	The costs associated with paying for daily necessities e.g., water, food, transport
Education and qualification	The level of scholarly education and formal qualification levels of citizens
Energy efficient (EE) appliances and equipments	High efficiency electro domestic equipment such as fridges, washing machines, etc.
Energy consumption	The amount of energy used by consumers
Energy demand	The amount of energy needed by consumers
Energy disconnections	The disconnection of consumers from an energy supply
Energy literacy	The level of understanding consumers have of the impacts of their energy consumption and understandings of the cost benefit ratios of investing in energy efficiency equipment
Energy prices	The market price of energy
External dependency	The degree to which a country (in this case Portugal) is dependent on energy imports from other countries to sustain a sufficient energy supply
Flexibility and diversity of energy market	The number of actors on the energy market and the range of offers (different energy packages) available to consumers
Fossil fuels	Finite energy sources which result in CO ₂ emissions including natural gas and oil products
Health and quality of life	Physical and mental health levels and ability to lead a dignified and comfortable life
Income	Monetary value earned by consumers (usually awarded per calendar month)
Legislation and regulation	National and European laws and regulations which framed the policy context of energy poverty in Portugal
Local technical support	The level of support available to guide consumers through technical processes, including decisions to purchase energy efficient equipment and applying for financial support for renovation through online portals
Maintenance and renovation of the building stock	Repair and quality improvement works undertaken on the building stock
Multi-scale policy incentives	Incentives such as financial support for renovation and energy bill discounts available at different governance levels (from national to local)
Professional training	Training and skills development activities for professionals in the retrofit trade
Quality and efficiency of building stock	The physical state of repair and energy efficiency performance of the building stock
Renewables	Non-finite energy sources including wind and solar energy
Renovation costs	The financial cost of undertaking building renovation
Social stigma	The social judging and labelling of consumers who are in situations of energy poverty
Thermal comfort and satisfaction of necessities	The level of comfort consumers can achieve within their homes and the degree to which they are able to access a sufficient level of energy to reach their daily needs
Trust	The confidence consumers have in governmental processes and representatives and in phenomena such as climate change and the energy transition
Vulnerability	The level of risk of experiencing energy poverty
Vulnerable groups	Groups in a situation of vulnerability including those in poor health, migrant and low-income groups

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