Journal of Cleaner Production 365 (2022) 132763

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Structuring the problem of an inclusive and sustainable energy transition – A pilot study

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ARTICLE INFO

Handling Editor: M.T. Moreira

Keywords:
Energy system
Multi-actor participation
Inclusive
Sustainable
Transparency
Portugal

ABSTRACT

The purpose of the article is to contribute to structuring the problem of how to advance a sustainable energy transition and achieve carbon neutrality goals while ensuring a democratic and inclusive process, by drawing on a pilot case – i.e., the energy transition in Portugal. By building on approaches and concepts from the Sustainability Transitions research field, the article explores perceptions, values, and concerns regarding distributed and centralized energy models; inclusivity and energy democracy; energy systems' sustainability concerns and the speed of the transition. The study draws on the hypothesis that stakeholders across the state, market, community and third sector spheres, while equally supporting decarbonization, have different perceptions, values, and concerns regarding the social, environmental, and technological dynamics of the energy transition that need to be better understood for accelerating the transition. The multi-method approach included interviews, a survey (N = 110) and a stakeholder workshop, to unpack the key values and preferences around energy system technologies, sustainability and inclusionary aspects, the role of centralized and distributed energy systems and new investments, namely in green hydrogen and lithium mining. The results indicate there is a significant convergence on the fact that decarbonization is a priority that needs to be supported by inclusive and democratic processes. Decentralization, energy communities and solar energy are extremely valued, and transparency and information sharing are crucial expectations for new lithium mining projects, large-scale solar and green hydrogen investments. These findings outline some avenues for future research, where participation and transparency become anchors for a sustainable and inclusive transition.

1. Introduction

A transition to renewable energy sources (RES)-based energy systems is important to decarbonize global economies, while also safeguarding wellbeing and quality of life (Fuchs et al., 2020). Aside from the urgency of a fast decarbonization, the energy transition offers an opportunity to implement new modes of governing and participating in energy systems, engaging citizens and stakeholders in a more inclusive way (Osunmuyiwa and Ahlborg, 2019; Revez et al., 2020).

In the European context, there has been a significant focus on policies that support new distributed systems (Gjorgievski et al., 2021), green hydrogen (Kakoulaki et al., 2021), and mining of required minerals (Gourcerol et al., 2019). The complexity of these different options and their relevance for decarbonizing economies is at the heart of current policy debates and raises several social acceptance and citizen engagement challenges (Liebe and Dobers, 2019). These concerns have been approached within Sustainability Transitions (ST) research (Geels et al., 2017; Markard et al., 2012), which understands transitions as long-term radical shifts of dominant socio-technical systems, or 'regimes', resulting from multilevel dynamics across regimes, socio-technical innovations and the socio-technical landscape (Geels, 2011; Geels et al., 2017). Accordingly, the transition to a RES-based system is a complex and non-linear transformation, requiring multiple solutions and a constant balancing of technological, social, and environmental concerns (de Haan and Rotmans, 2011; Liu et al., 2007). It can be characterized as an unstructured problem, implying agreements

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https://doi.org/10.1016/j.jclepro.2022.132763
Received 2 February 2022; Received in revised form 18 May 2022; Accepted 16 June 2022
Available online 20 June 2022
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between multiple actors, who hold different values and perceptions about the problem, and who are faced with uncertainty regarding possible solutions (Mingers and Rosenhead, 2004). Although leading globally to cleaner energy production and consumption, the energy transition is fabricated through local and regional processes, involving diverse context-specific material and immaterial resources, disturbing power and institutional dynamics, as well as social and environmental contexts (Bues and Gailing, 2016; Labussière and Nadaï, 2018). In this context, the purpose of the article is to contribute to structuring the problem of how to advance in an energy transition that enables achieving carbon neutrality goals while ensuring democratic and inclusive processes, by drawing on a pilot study (i.e., Portugal's energy transition).

Energy justice and environmental justice considerations are central to this problem (Bouzarovski and Tirado Herrero, 2017; Healy and Barry, 2017; McCauley and Heffron, 2018). By combining a socio-technical and an energy justice approach (Sovacool et al., 2017), the justice-related aspects of the ongoing relationships between socio-technical innovations and the wider regimes and landscape are brought to the foreground (Jenkins et al., 2018). These aspects include the relative openness of institutional and corporate environments, such as access to financial mechanisms and other means of support, and understanding the different relationships and power dynamics established in relation to energy production, distribution, and consumption (Bues and Gailing, 2016; Gjorgievski et al., 2021). Also, institutional enabling and structural conditions, such as multilevel policy and regulatory frameworks, need to be understood. Calls for energy democracy, ensuring higher participation of citizens in decision-making processes, are equally crucial for a more inclusive transition (Burke and Stephens, 2017). Furthermore, environmental justice concerns, guaranteeing the most vulnerable communities and citizens are included in the process, rather than reinforcing pre-existing inequalities, should not be overlooked (Cowell et al., 2011; McCauley and Heffron, 2018).

Thus, a first step towards a sustainable and inclusive transition, while considering the multi-stakeholder, multi-scale, and multilevel dimensions of the processes, is to establish the grounds for implementing a new energy system by investigating questions such as: "what is the real problem and its different dimensions? How to decide what to do about the problem and who to involve?" (Frantzeskaki et al., 2012; Woolley and Pidd, 1981). It is equally relevant to reduce uncertainty by fostering a process of knowledge exchange between different stakeholders and enable negotiation and agreements between divergent views (Hisschemöller and Cuppen, 2015; Hisschemöller and Hoppe, 1995). While doing so, different dimensions of the problem come to the foreground, and enable gaining insight into interrelated social, economic, environmental as well as technological challenges and opportunities. These needs are the focus of problem structuring methods (Woolley and Pidd, 1981), which have been applied in interdisciplinary research fields such as ST research (Loorbach and Rotmans, 2010).

This article presents the results of a pilot research taking place in Portugal (although the approach is meant to be replicable in other European countries as well). Despite its ambitious decarbonization goals, Portugal faces significant challenges in implementing an inclusive transition due to high levels of energy poverty (Kyprianou et al., 2019) and poor active citizenship (Prados et al., 2022). Diverse conflicting interests and concerns exist related to mining projects, with Portugal being the biggest European potential producer of lithium (Chaves et al., 2021). The implementation of large-scale solar installations and distributed energy systems are developing at distinct rhythms, with recent literature pointing to specific stakeholder interests being privileged by mainstream policies (Sareen and Nordholm, 2021; Silva and Sareen, 2021). In this context, research into how to navigate through the various, and possibly conflicting, concerns and preferences of stakeholders regarding the interrelated social, environmental, and technological dynamics of the transition is still piecemeal. To address this research gap, the study builds on the hypothesis is that stakeholders across the state, market, community and third sector spheres, while equally supporting decarbonization, have different perceptions, values, and concerns that need to be better understood for fostering an inclusive and sustainable transition to a RES-based system.

2. Methodology

The methodology follows a participatory problem structuring approach (Hisschemöller and Cuppen, 2015; Hisschemöller and Hoppe, 1995), which seeks the integration of differing views in relation to a particular problem. The specific problem is how to advance with the energy transition and achieve carbon neutrality goals while ensuring a democratic and inclusive process. Portugal is an interesting pilot because it was quick to develop a plan for carbon neutrality by 2050 – i.e., the government's Neutrality Roadmap (RNC2050, 2018) -, and advance with the transposition of new EU directives (i.e., REDII) to national law (Campos et al., 2020). The government also aims to invest in green hydrogen technology to advance in decarbonizing energy systems (Kakoulaki et al., 2021). Also, Portugal has lithium reserves and new mining projects are proposed (Gourcerol et al., 2019), similarly to other European countries (i.e., Finland, France, Ireland), yet raising significant concerns regarding local environmental and social impacts (Chaves et al., 2021). Still, the country needs to tackle energy poverty and address social acceptance challenges (Prados et al., 2022), as large-scale solar installations and other RES technologies are expanding (Silva and Sareen, 2021). In this context, three conceptual dimensions of the problem were identified, namely the structure of the energy system, social practices (e.g., related to new technologies and flexibility), and the speed of the transition. These dimensions led to identifying key research questions (RQ) to guide the participatory structuring of the problem, namely:

- RQ1 How are distributed and centralized energy models perceived and valued?
- RQ2 How are inclusivity and energy democracy valued and what concerns exist?
- RQ3 What concerns exist for energy systems' sustainability and the speed of the transition?

Guided by these questions, qualitative and quantitative data collection and analysis methods were combined, enabling the triangulation of different methods (Gibson, 2017) to collaboratively redefine the problem and integrate empirical results, thus enabling a clear formulation of divergent perceptions, concerns and values of stakeholders to further formulate the problem and its alternative solutions. In what follows, the different methods applied (see also Fig. 1) are described (see Fig. 2).

2.1. Mapping and involving stakeholders

Stakeholder involvement was guided by a Multi-actor Perspective (MaP), which is a conceptual framework for understanding shifting multi-actor power relations in transitions (Avelino and Wittmayer, 2016). The MaP offers a categorization of actors regarding different levels of aggregation, explicitly describing how different categories reproduce existing power relations and dominant institutional logics. Actors are understood as a 'social entity, that is, a person or organization, or a collective of persons and organizations, which is able to act' (Avelino and Wittmayer, 2016, p. 635). Four categories are identified, namely, the state, market, community, and the third sector. These categories may be relevant at different levels of aggregation, namely as sectors (e.g., energy regulators); individual actors (e.g., policymakers); and organizational actors (e.g., NGOs; energy companies; research institutes). In this study, actors were mainly considered from a sectorial and organizational perspective (see Table 1).

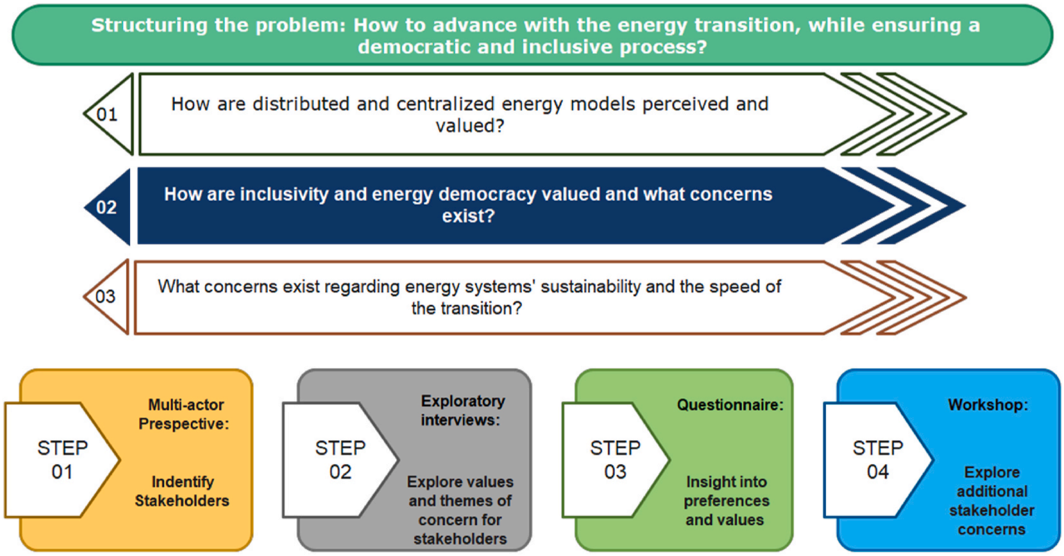

Fig. 1. Research questions and methodological steps for structuring the problem.

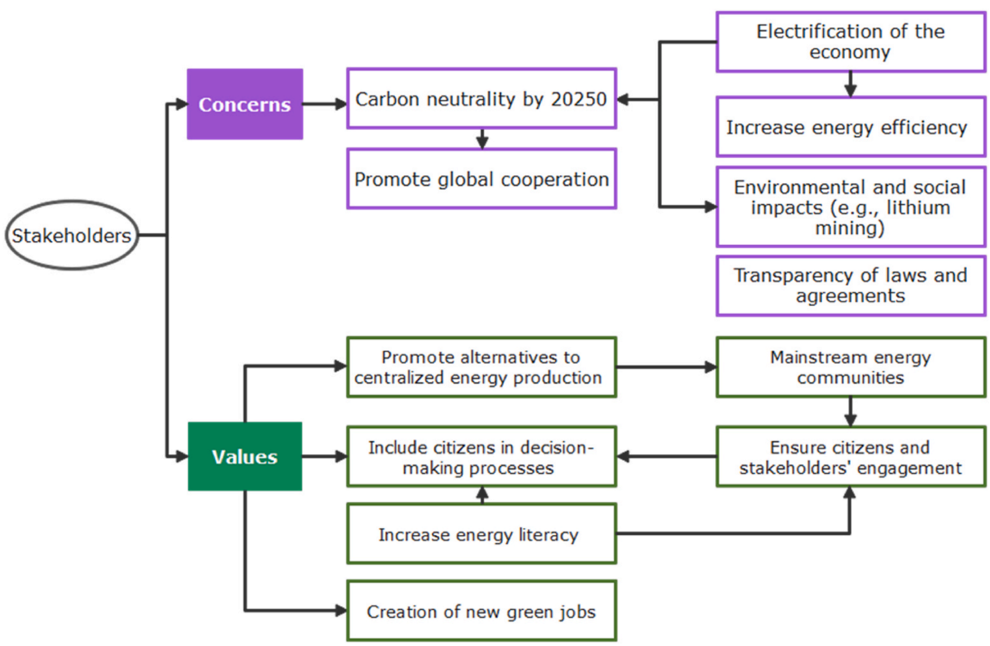

Fig. 2. Concept map of key concerns and values of (N = 6) stakeholders interviewed.

2.2. Exploratory interviews

Semi-structured interviews were conducted with energy system stakeholders (N = 6), from each of the four actor categories. This exploratory phase of the research was done through an interpretivist stance of the gathered data (McChesney and Aldridge, 2019), seeking a better understanding of stakeholders' experiences, while benefiting from their expert knowledge of the energy system's dynamics (Gunnarsdóttir et al., 2021). The interviews departed from a scenario-based structure (Beighton, 2021) to facilitate the articulation of the interviewees' perspectives and to elicit a deeper discussion of the available options for innovating the energy sector, considering the structure of the new system, changes in practices, and how the transition may/should develop over time.

The results were analyzed through an interpretivist perspective looking for emergent codes and themes (Blair, 2015) directly derived from the content analysis of the collected data (Stemler, 2000). Despite the small sample of interview participants, the results paved a constructive sense of the relationships between the identified themes and the expressions of values and concerns among stakeholders, thus informing the following methodological stages.

2.3. Questionnaire

Guided by the identified questions for structuring the problem and exploratory insights from the interviews, an online self-administered questionnaire (N = 110) was implemented to gain further insight into actors' preferences, values, and perceived challenges and opportunities for the transition. Responses were collected between October 15, 2021, and December 30, 2021, and the questionnaire included five sections.

First, questions focused on independent variables, including gender, occupation, region of Portugal, and age. These variables were included

Table 1
Actor categories and organizations identified and invited to participate in the study.

Actor Categories	Actors	Organization type	Number of organizations contacted
Third Sector	Academia	PhD programs	2
		Research institutions	10
	Civil Society	Environmental associations	3
		Non-governmental associations	2
		Labor unions	2
		Agriculture associations	14
		Renewable energy cooperatives and associations	4
		Consumer organizations	1
Community	Community groups	Informal community groups	5
	Citizen's participation platforms	Citizen forum	1
Market	Energy Services and Products	Consulting companies	11
		Energy product companies	18
		Utility companies	2
		TSO/DSO	1
		Industrial associations	9
		Energy investment companies	2
State	Policy and Regulators	Central government bodies	8
		Regulatory bodies	2
		Municipal agencies	19
		Municipalities	3

as potential demographic factors influencing values and perceptions (Koirala et al., 2018). The following sections had mainly ordinal variables, posed in positive terms, using a 1 to 5 Likert scale (i.e., 1 = not important and 5 = very important). All questions included a N/A option and of the final 110 valid responses, only 93 responded to all questions.

The second set of questions aimed to understand the values attributed to different aspects of the transition, namely the need to reduce emissions; the need to ensure inclusion; the need to protect biodiversity, the importance of reducing energy poverty, and increasing energy efficiency.

A third set of variables focused on the values attributed to distributed and centralized energy systems. Questions explored factors such as the importance of citizen participation and battery storage in the case of a distributed system, and the relevance of large investments and of ensuring economic and social benefits for local populations, in the case of a centralized system. This section included two nominal variables informed by previous research on the motivations for self-consumption (Brown et al., 2019; Horstink et al., 2020), where respondents were asked to select from a list of key opportunities and challenges for participating in distributed systems (e.g., renewable energy communities).

In the fourth section, respondents assessed the importance of different variables for sustainability (e.g., flexibility, storage, investment capacity, energy literacy, efficiency in distribution, creation of green jobs, energy democracy and international cooperation). In addition, two questions were included to assess values attributed to hydrogen technology and lithium mining, The last section comprised three questions on the preference for the speed of the transition (i.e., also using a Likert scale of 1 = very slow to 5 = very fast) and the importance of citizens' participation and transparency.

The survey followed a non-probabilistic quota sampling approach (Kälviäinen et al., 1995), considering as its population all actor categories actively participating in developing the Portuguese energy sector. A geographical representation of continental NUTS II regions was attempted. A total of 120 actors were identified (see Table 1), and 145 emails were sent out. To enhance gender diversity, actors who received the survey were asked to share it with their female colleagues and peers. Considering the requests for sharing the survey, it is estimated that the survey circulated among 300 email recipients. A participant information sheet was included in the email, explaining the goals of the survey, and an informed consent form made up the questionnaire's starting page.

Statistical analysis was conducted using SPSS (v28) software. The analysis included descriptive statistics (i.e., frequencies and statistical descriptions), correlations (Pearson correlation) and factor analysis. While descriptive statistics offered insights into the values attributed (through Likert scales) to various aspects of the transition, correlations analysis enabled identifying interrelations between opinions and values expressed in relation to different variables. Some variables were analyzed using factor analysis (Sherren et al., 2021), which is a useful method to find relevant factors among observed variables and reduce the number of variables by exploring commonalities (e.g., opportunities, challenges) and variance across the data.

2.4. Stakeholder workshop

A group of 35 participants representing the four actor categories were invited to a stakeholder workshop to explore in further depth the results of the survey, and topics that were not sufficiently covered (e.g., transport). To prepare workshop participants, the preliminary results of the survey and interviews were presented in a webinar (conducted two weeks earlier). Workshop discussions took the form of an online "world café" (December 3, 2021), attended by 18 of the invited participants. Using online 'break out rooms' participants discussed their preferences, considering key challenges and opportunities for distributed and centralized energy systems, flexibility and storage technologies and practices, the transport system, and participation and transparency. Each participant had opportunity to participate in each breakout room and provided her/his input on each topic. Each room was facilitated by an expert on the topic, to guide discussions and pose questions that would encourage critical thinking. Qualitative data analysis of the results of the workshop relied on a thematic coding analysis using NVivo software to create and explore key themes and codes, representing different stakeholder preferences and ideas (Blair, 2015).

3. Results

3.1. Exploratory interview results

The results of exploratory interviews offered a basis for the integration of different stakeholder concerns and values, thus enabling a better framing of the cross-cutting objectives of decarbonization, inclusivity and energy democracy. Regarding decarbonization, interviewees were clear on the need to reach carbon neutrality by 2050. Related to this priority, respondents highlighted the importance of the "electrification of the economy", "promoting global cooperation", "adapting urban structures to decentralized production" and "mainstreaming energy communities". Democratic processes were equally valued. Citizens and stakeholders should be "well-informed of existing plans"; the "transparency of laws, contracts and agreements" is crucial, and citizens and stakeholders should be able to "participate in decision-making processes", supported by effective communication and engagement strategies. Inclusivity was framed in relation to reducing energy poverty, but also to ensuring wide participation of citizens in the transition (e.g., as prosumers), and the need to increase "energy literacy".

3.2. Survey results: Stakeholder preferences and values

3.2.1. Respondents

The survey included 110 valid responses, although only 93 responded to every question. 82.7% of respondents were between 18 and 54 years old, with a mean age of 35 years old. 32.7% were women and 67.3% man (Fig. 3). Both age and gender were independent variables, as the Chi-test (4.210) did not reject the null hypothesis ($p = 0.378$).

Regional distribution was challenging to achieve, with 58.18% respondents from the Lisbon area, 28.18% from the North of Portugal and the remaining 13.63% from the Centre, Algarve and Alentejo regions (Fig. 4). This distribution largely reflects the Portuguese energy sector, as all major utility and energy services companies have their headquarters in the Lisbon metropolitan area and the North (the two main regions of respondents).

82.7% of respondents were full-time employed, and 17.3% were employed part-time, students or retired. As for their professional activity, 25.5% were from academia and research, 19.1% from services, 13.6%, represented cooperatives or associations, the remaining 40.9% represented industry (8.2%), investment (1.8%), agriculture associations (2.7%), non-governmental organizations (9.1%), central government (9.1%), and local or regional governments (10%) (Fig. 5).

3.2.2. Distributed and centralized energy systems

A multiple answer analysis of the main opportunities chosen by respondents for implementing and/or participating in distributed energy systems indicates as top opportunities the reduction of energy costs (88 responses), contribution to decarbonization efforts (80) and reducing energy consumption (52) (Fig. 6).

Next, a multiple answer analysis of the main challenges listed by respondents for implementing and/or participating in new distributed energy systems indicates as main challenges financing the installation (77 responses), administrative complexity (50) and difficulties in community decision-making (47). (Fig. 7). Respondents also described "other opportunities", such as: "higher environmental awareness", and "changing practices, such as moving loads to solar time".

"Other challenges" were equally stated, such as "urban buildings are not prepared (small roof areas)".

According to 97 respondents (13 had no opinion), a distributed energy system is more important than a centralized energy production model with 48.5% who "agree" and 26.8% who "strongly agree". By comparison, 23.2% "agree" and 3.2% "strongly agree" that the centralized model is the most important (although 15 respondents had no opinion on the centralized model) (Fig. 8).

The combined value of different variables characterizing distributed

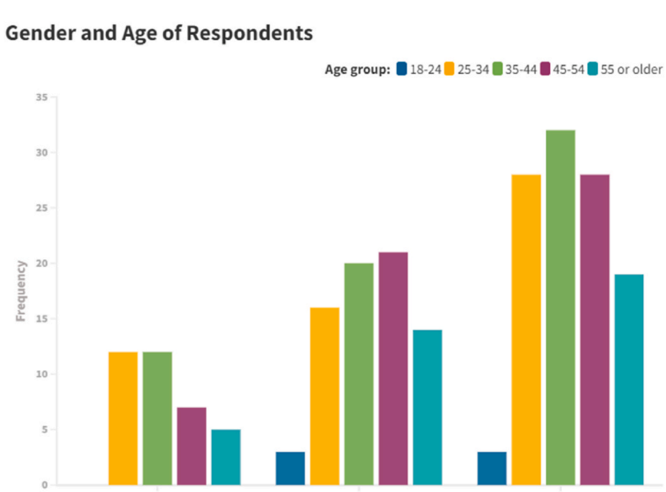

Fig. 3. Frequency (number of cases) of Gender and Age (N = 110).

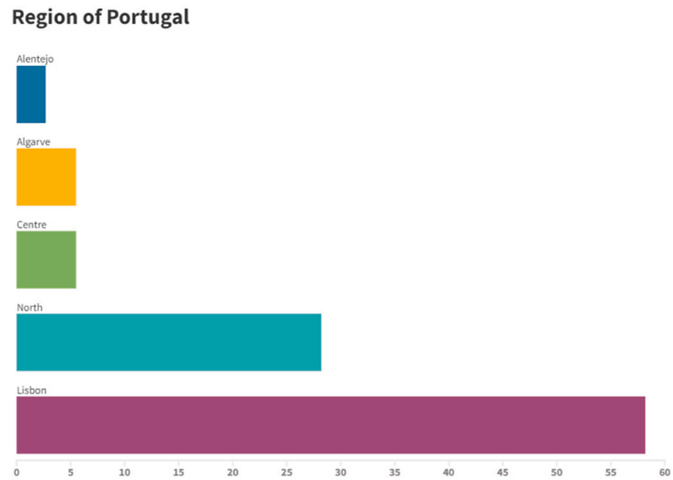

Fig. 4. Regional NUTS II distribution of survey respondents.

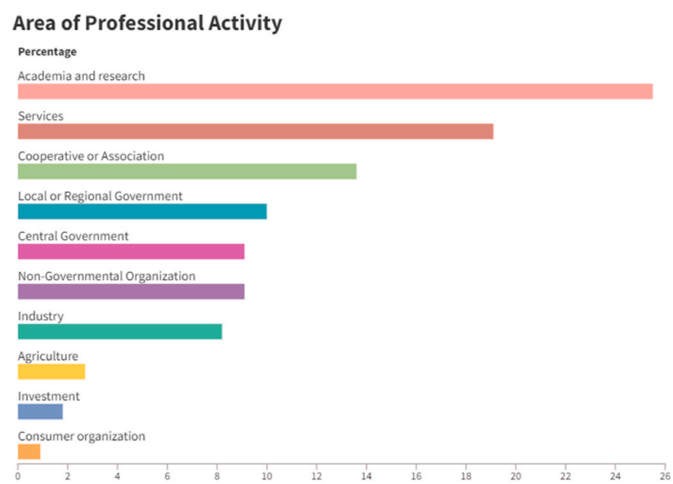

Fig. 5. Area of current professional activity (frequency in percentage) (N = 110).

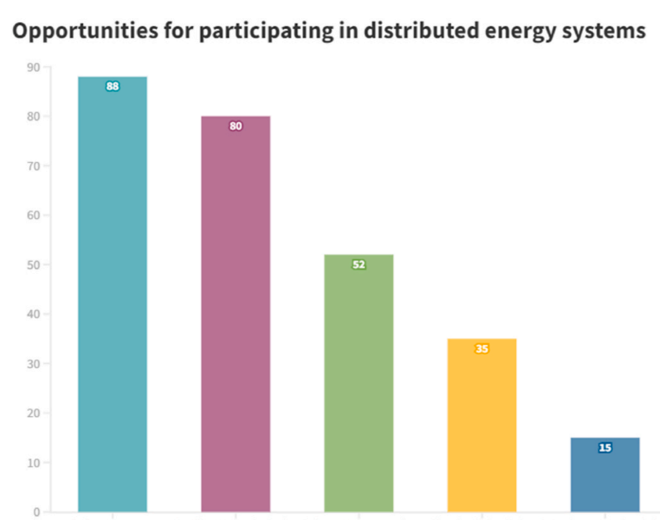

Fig. 6. Frequency (number of cases) of the opportunities for implementing or participating in distributed energy systems such as energy communities.

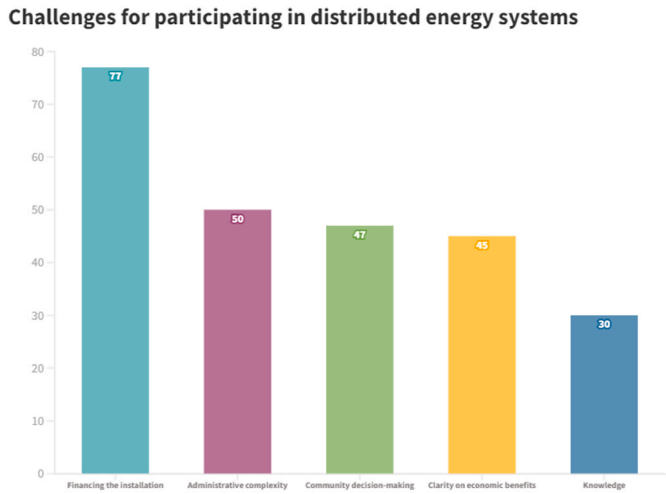

Fig. 7. Frequency (number of cases) of the challenges for implementing or participating in distributed energy systems such as energy communities.

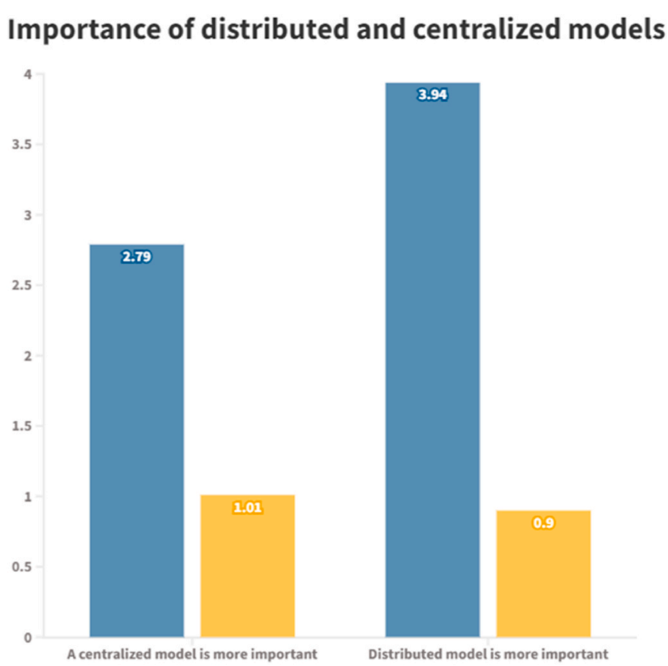

Fig. 8. Comparison of mean values between the importance attributed to a centralized model and a distributed model (including standard deviation).

energy systems was calculated based on a factor analysis of seven variables ("distributed model is more important to the transition", "distributed model implies a slower transition", "distributed model is only possible with battery storage", "administrative processes are highly complex", is "more participatory and collaborative", and "importance of renewable energy communities").

However, 20 respondents had no opinion on some of the different aspects of the distributed model; thus, the factors were computed for only 90 responses. Still, the KMO test (>0.5) indicated a minimal adequate sample (i.e., 0.6) and a statistically significant result (<0.004). The resulting two factors were labelled as "Challenges" (including "slower transition", "need for battery storage" and "administrative complexity") and "Opportunities" ("more important for the transition", "more participatory and collaborative", "importance of renewable energy communities"). After comparing the means of the newly computed factor variables, "Opportunities" were found to be more relevant than

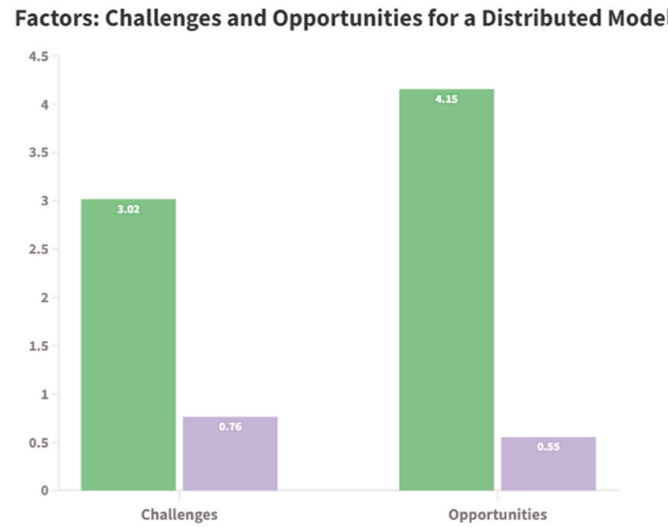

Fig. 9. Comparison of the means of two factors (i.e., Challenges and Opportunities) of a distributed energy model (and standard deviations).

"Challenges" (Fig. 9).

As regards centralized systems, the commonalities between different aspects characterizing centralized energy systems were analyzed using a factor analysis of a set of variables ("more important for the transition", "involve local communities", "economic and social benefits for local communities", and "implies large new investments"). 15 Respondents had no opinion, so the factors were computed for only 93 responses. Still, the KMO test (>0.5) indicated a minimal adequate sample (i.e., 0.48) and a statistically significant result (<0.001). The resulting two factors were labelled as Challenges (involve local communities; economic and social benefits for local communities) and Opportunities (more important to the transition and implying large investments). After comparing the means of the newly computed factor variables, analysis shows that contrary to the distributed model, opportunities had a lesser weight than challenges (Fig. 10).

3.2.3. *Decarbonization, inclusivity and democratic participation*

Concerning stakeholder preferences and values in relation to the transition to a RES-based system, 74% of (N = 110) respondents considered "very important" (attributing a score of 5) "reducing

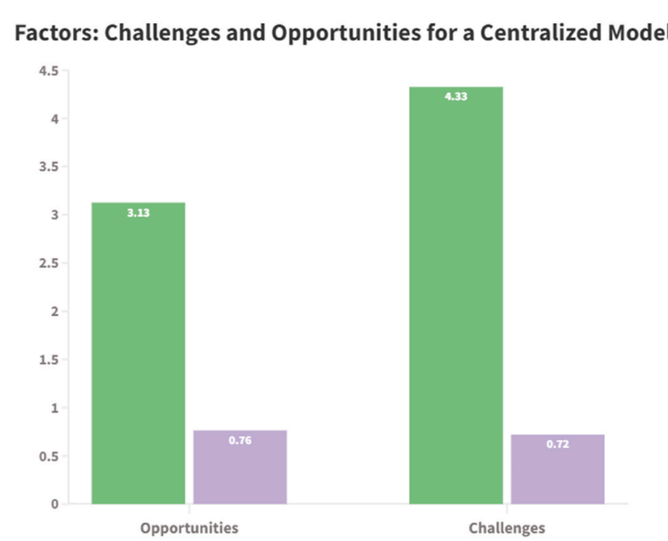

Fig. 10. Comparison of the means of two factors (i.e., Challenges and Opportunities) of a centralized energy model (and standard deviations).

emissions and reaching carbon neutrality". An "inclusive energy transition" also scored 5 in 80% of cases; "protecting biodiversity" in 73.6% of cases; "reducing energy poverty" in 69.1%, and "increase energy efficiency" in 49% of cases. In addition, 88.2% of respondents found that "citizens' participation in the transition" and "transparency" are "very important".

Factor analysis was applied to distil the commonalities among these variables (N = 97). The Kaiser-Meyer-Olkin (KMO) measure (>0.5) test indicated the sample to be adequate (i.e., 0.7) for a factor analysis, while Bartlett's test (>0.5) indicated a statistically significant result (<0.001). The analysis resulted in two main factors as important overall aspects of the energy transition, which were labelled as "Sustainable and Inclusive" (i.e., importance of reducing emissions, an inclusive transition, protecting biodiversity, reducing energy poverty and increasing energy efficiency) and "Participatory and Transparent" (i.e., the importance of citizens' participation and importance of transparency). After calculating the scores for each new variable, "Sustainable and Inclusive" had a slightly higher mean, although the two factors were highly valued (Fig. 11).

In addition, a Bivariate Pearson Correlation indicated a correlation between the importance attributed to reducing emissions and the importance of ensuring an inclusive energy transition. Pearson's bivariate correlation coefficient shows a medium positive linear relationship between the two variables (i.e., 0.639), which is significantly different from zero (p-value is < 0.001).

3.2.4. Speed of the transition and energy systems' sustainability

As regards the speed of the transition, 40% of respondents favored a "fast transition", followed by 32.7% who preferred a "moderately" paced transition. Only 12.7% preferred a "very fast transition" and only 2.7% thought the transition should be "slow". A linear relationship is found between the preferred speed for the transition and the importance of an inclusive energy transition. Pearson's bivariate correlation coefficient shows a medium positive linear relationship between both variables (i.e., 0.227), which is significantly different from zero (p-value is < 0.001, at 0.025). Thus, respondents both valued the speed of the transition (mean value is 3.7 on a scale from 1 to 5) and inclusion (i.e., with a mean value of 4.7), indicating that integrated solutions for a rapid and inclusive transition process are likely to be equally valued.

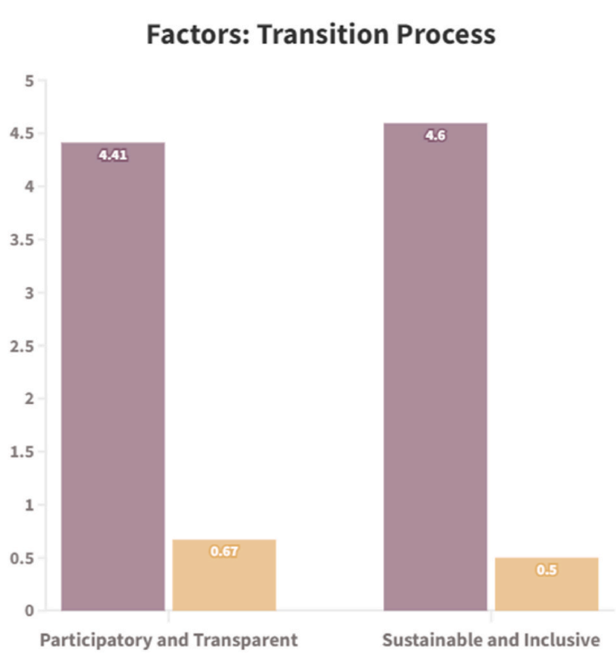

Fig. 11. Comparison of the means of two factors: Participation and Transparency and Sustainable and Inclusive transitions (and standard deviations).

Respondents highly valued RES technologies as the means to achieve environmental sustainability and advance with the transition. Solar energy (73.6% found it "very important") and wind energy (53.6% found it "very important") were the top preferences, with biomass being the less favorite (only 26.4% found it "very important"). Battery storage was considered slightly less important than hydrogen, although both had positive values. Thus, all technologies were positively valued by respondents, with means between 3.7 (biomass and biogas) and 4.6 (solar) (Fig. 12).

Regarding opinions on lithium mining and green hydrogen investments, only 96 responded, and 14 respondents had no opinion on these issues. Lithium mining had a slightly low value for respondents (mean of 3.3, with only 10.9% finding it "very important", and 24.5% "important"). Hydrogen investments in Portugal were also not significantly valued (mean 3.8, with 31.8%, finding it "very important" and 24.5% "important").

Different aspects relevant to energy systems sustainability were combined using factor analysis of seven input variables ("flexibility of the system", "investment capacity", "energy literacy", "efficiency in distribution", "creation of green jobs", "energy democracy" and "international cooperation") which respondents were asked to assess considering their importance to sustainable energy systems. Only 94 responded, and 16 respondents had no opinion.

Kaiser-Meyer-Olkin (KMO) measure (>0.5) test indicated an adequate sample (i.e., 0.64) and Bartlett's test indicated a statistically significant result (<0.001). The two resulting factors were labelled as "Social Benefits" (includes the creation of green jobs, energy democracy, and international cooperation), and "System Capacity" (flexibility of the system, investment capacity, energy literacy, and efficiency in distribution). After computing the scores for each new variable, "System Capacity" had the highest mean, although the two factors were highly valued. These two factors offer a synthesis view of how respondents value a balance between systems' capacity and the wider societal benefits for ensuring the sustainability of the system (Fig. 13) (see Fig. 14).

3.3. Workshop results: Stakeholder concerns for energy system futures

3.3.1. Distributed and centralized systems

The workshop results highlight the different ideas, concerns, and solutions envisioned by participants for distributed and centralized energy systems. Centralized systems need to follow transparent plans, involving citizens and local populations, including the "creation of participatory decision-making spaces". These systems can help reduce final energy costs for consumers (due to higher penetration of RES in energy markets) and were found to "facilitate large-scale implementation of green hydrogen" yet are challenged by the need for rural transformations, competing with other priorities – i.e., farming, rural tourism, and biodiversity protection.

New distributed systems can provide "alternatives for more vulnerable communities", helping to reduce energy poverty. Here, "energy literacy" may play a critical role and a higher decentralization is considered a pathway for "empowering citizens". Renewable energy communities were recognized as offering "social and economic benefits for local communities" yet could be taken over by large utilities and "become a business", losing their non-profit dimension. Currently, high administrative burdens make it difficult to advance with community projects and energy communities are developing "very slowly", though there are hopes for a "major leap forward". "Information deficit" and language being "very academic and mathematical" were highlighted as barriers.

The flexibility of new energy systems is dependent on new services, based on demand-response, "dynamic tariffs", and new technologies (i.e., "smart meters, smart devices"). Such changes require high levels of (self-)consumers' involvement, through the adoption of "new practices", including "changes in work routines", but also investments in new energy infrastructures. However, it was argued there is little awareness

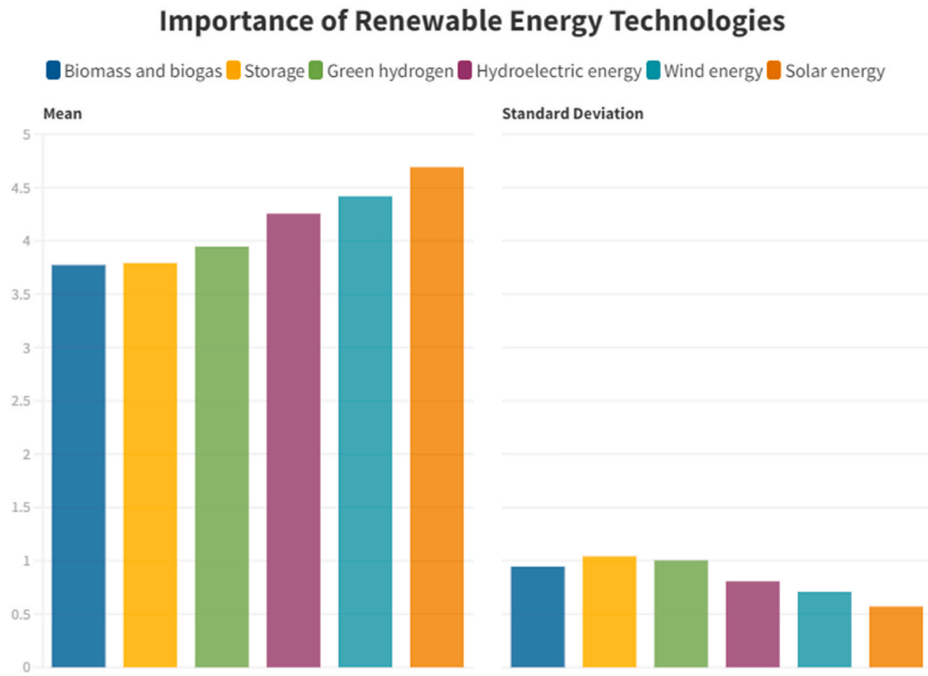

Fig. 12. Comparison of the mean values on the importance of different renewable energy technologies (N = 110).

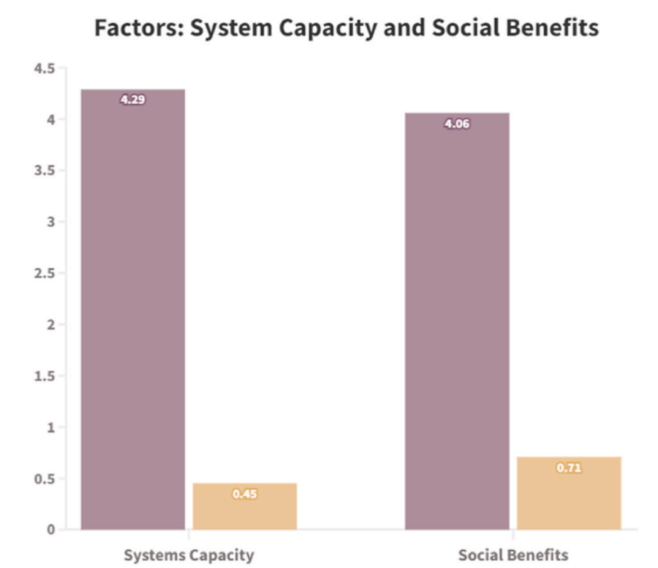

Fig. 13. Comparison of the means of two factors (i.e., System Capacity and Social Benefits) relevant to energy system sustainability.

and communication about these services.

Storage technologies and practices were observed as critical to "expand smart distribution networks" and enable storing "energy at different times of the day, as well as seasonally". Despite a consensus for diversity in storage technologies, participants thought green hydrogen should be prioritized to "achieve carbon neutrality goals". Green hydrogen is realized as a solution for large consumers, "highly scalable", with applications for mobility, for long-term storage, and "for heavy transports, aviation, and sea transports". Hydrogen is thus considered important for supporting the "electrification of energy systems" through a multisectoral approach, "increasing national energy security and independence". Nevertheless, it is perceived as a very expensive technology, "not viable at a small scale", requiring incentives for its development, and with costly technological requirements for storage and transport.

Battery storage is important to increase electric mobility, with clear advantages of "vehicle-to-grid systems" and for "balancing the energy grid for self-consumption and distributed production". Batteries enable increasing self-sufficiency and autonomy of energy systems, but stakeholders had expectations for more "holistic approaches" to energy storage, including thermal solutions combined with energy efficiency measures.

3.3.2. Inclusivity, participation, and democracy

The need for higher transparency and inclusive participation of citizens were cross-cutting issues. Transparency implies early sharing of plans, full clarification on activities, costs, and duly informing local populations. The need for increased participation was equally highlighted. Here new forums for participation could be set up, including "citizen assemblies". Local governments were valued for their potential role in facilitating participation, by providing "platforms based on the interests and preferences of citizens". It was consensual that "the earlier (local) populations are involved in plans for new energy installations the easier the implementation process". Fostering energy democracy was a concern. Stakeholders claimed that citizens' involvement is typically done only in the final stages of a project, which does not provide local communities with "sufficient time to present their views on the subject". Still, public consultations are found to have limited participation, and "people are not appropriately engaged nor included". Instead, "large utilities hold the power", both figuratively (i.e., decision-making power) and materially speaking (as community-led investments are minimal). In this context, higher "articulation between local and central governments" was believed to be critical to empowering citizens and fostering inclusivity.

3.3.3. Speed of the transition – the issue of transport

The transition should be fast, but the transport system is considered a key bottleneck for Portugal. Participants highlighted that current "piecemeal policies (e.g., cycling routes)" are far from enough to ensure a fast transition. The electrification of all means of transport is necessary. While current solutions are "mainly technological", participants found "incentives" are important to "change local consumption". Introducing "carbon budgets" could be a possibility, but also offering

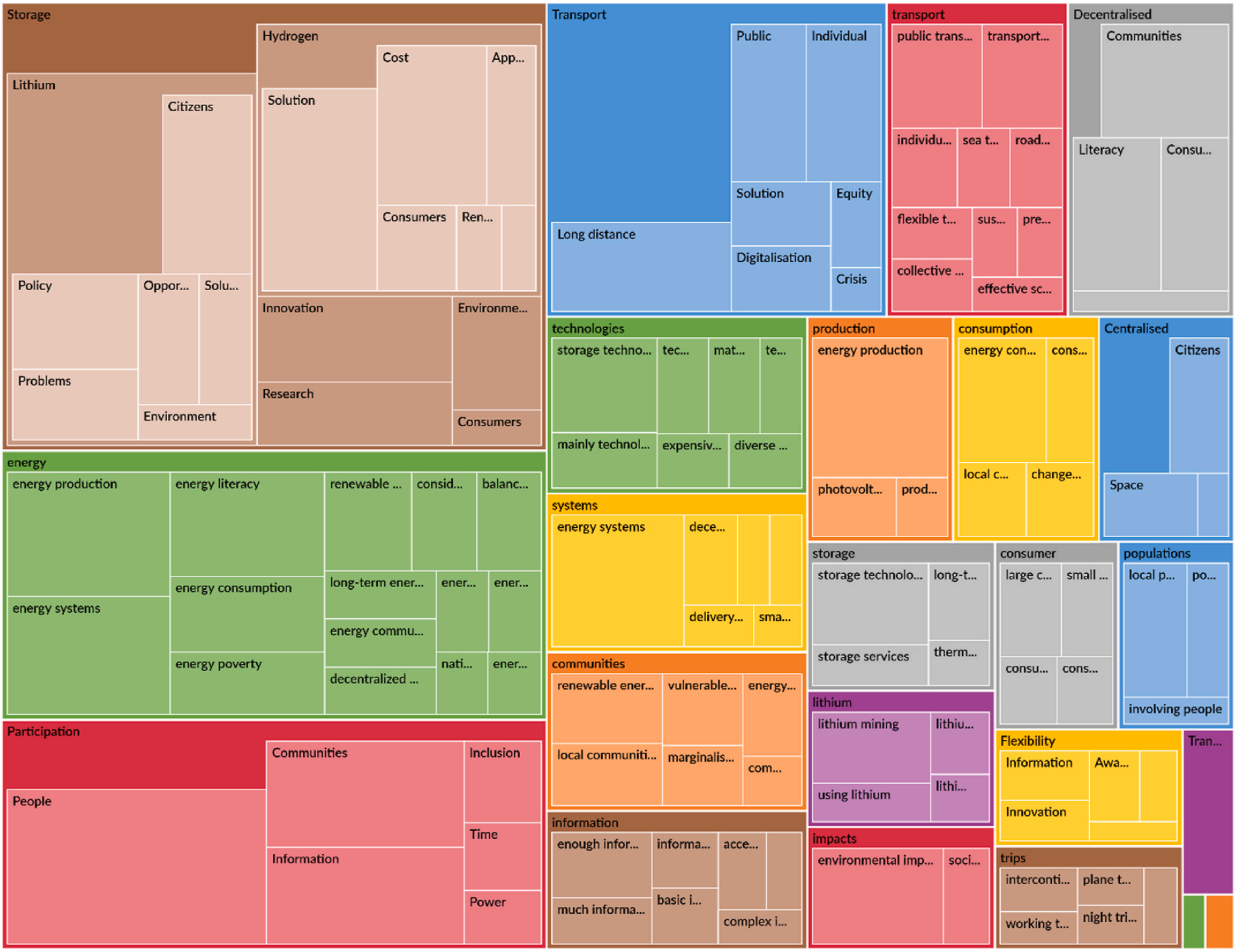

Fig. 14. Summary of codes and themes resulting from the workshop.

incentives for public transport ("should be free"). As cities have been "designed for cars", a new design is needed, based on the idea of, for instance, a "city, where people can get around to all basic places in a 15-min ratio". Spatial planning is thus essential. An efficient and optimized network of public transport, as well as "free and effective school transports", articulated with working routines would be good solutions. Trains should be the "preferred transport for trips of less than 2500 km", and fossil fuels reserved for intercontinental trips. Thus, new railroad and train investments are needed. Digitalization and automated systems (e.g., "last-mile delivery systems") were not seen as optimum solutions, due to their "potential massification" and resulting pollution. Participants also highlighted equity issues. For instance, a "higher cost of plane trips affects mainly lower-income citizens", while the richest individuals will still be able to "keep their private jets."

Lastly, lithium mining in Portugal is a potential bottleneck for the transition. Participants criticized the lack of clarity and information on the "lithium reserves and the viability for their exploration" in Portugal, and the systematic lack of information provided to local populations. If lithium can be used with a low level of negative economic and environmental impacts, participants prefer it to be mined in Portugal (where environmental laws are rigorous) than in "parts of the world where mining could have potentially higher negative environmental and social impacts". Moreover, any mining activity will require a "true environmental and economic evaluation". Since mining is destined for lithium exports, a positive impact on the national economy is expected. The importance of continued research for "diversifying storage technologies" was highlighted, but also research into effective means for "recycling batteries".

4. Discussion

Stakeholders significantly value distributed energy systems and support their expansion, recognizing the inevitability of combining different structures (i.e., centralized and distributed) in new energy systems. The speed of the transition faces bottlenecks related to the resources needed to advance with RES-based systems, both in terms of the vast amounts of minerals required (Valero et al., 2018), and inevitable rural transformations (Calvert et al., 2021), but also concerning the need for expanding new organizational models (e.g., energy communities), and new decision-making processes, including in land-use planning, that significantly increase stakeholder and citizens' engagement. Thus, decarbonization is a priority that needs to be supported by inclusive and democratic processes.

Despite the preference for distributed RES systems, administrative barriers are delaying implementation in Portugal, revealing a gap between stakeholder preferences and energy policies, similarly to other countries (Szendro et al., 2012; Walnum et al., 2019). Social inclusion concerns were raised in the scope of distributed systems. For example, regarding how such systems can effectively help curb energy poverty, rather than increasing energy system related inequalities (Lennon et al., 2020; Osunmuyiwa and Ahlborg, 2019). These issues convey fears that participation in new energy systems is not equally accessible to all, considering both national as well as cross-country comparisons (Feenstra and Özerol, 2021; Moniruzzaman and Day, 2020). Inclusion is equally relevant in new transport and mobility systems, where equity concerns were found to require innovative public policies, as individual transports are likely to become increasingly exclusive (Sovacool et al., 2019).

Distributed systems and solar energy's high social benefits and potential for "justice flexibility" were also valued (Heffron et al., 2021; Zwickl-Bernhard and Auer, 2021). However, flexibility and storage were found to come with different challenges. New flexibility designs and regulatory frameworks should integrate distributional, recognition and procedural justice aspects and ensure fair access to energy storage capacity (Milchram et al., 2020). Likewise, the potential of flexibility and storage for increasing energy justice depends on new social practices (e.g., new consumer routines), transparency, and established power relationships (Andoni et al., 2019; Hwang et al., 2017), as well as the availability of infrastructures to support inclusive flexibility designs (Schweiger et al., 2020).

Stakeholders valued biodiversity protection next to decarbonization and recognized the relevance of reducing any negative socio-environmental impacts, particularly in the case of large solar power plants (Hirbodi et al., 2020; Turney and Fthenakis, 2011), and mining projects (Kaunda, 2020; Liu et al., 2019). Considering the significant amount of new minerals needed to build new RES-based systems (e.g., cobalt, lithium, cadmium, copper, etc.) and the understanding that extractive industries are leaving an environmental degradation footprint across the globe (Herrington, 2021), stakeholders called for complete transparency and openness regarding mining projects, backed by the appropriate involvement of local populations. In this context, the adoption of small-scale mining projects, more supportive of local livelihoods could be an important avenue for the local transition (Sovacool et al., 2020).

Considerations about the lifecycle of lithium batteries were aligned with hopes for the development and market uptake of new battery technologies, as well as better returns on hydrogen investments (making the technology more affordable). Here, participants have set their hopes for the future on economic and technological fixes, which can nevertheless lead further into unsustainable pathways (Blühdorn, 2017; Selinger, 2013).

As evidenced by stakeholders' perspectives, transparency and information sharing should be at the forefront of new mining projects, and large-scale solar and green hydrogen plants. Likewise, citizens' participation was extremely valued by all actors, who recognized effective tools for participation were still lacking (Bidwell, 2016; Bourazeri and Pitt, 2018). Different factors have been found to determine citizens' willingness to participate, including environmental concerns, energy literacy and knowledge, (Koirala et al., 2018), yet stakeholders found these were still not effective in fostering high levels of participation.

5. Conclusion

Problem structuring highlighted how energy system infrastructures, and their technological, production, distribution, and consumption dynamics relate to diverse social, economic, political, and environmental aspects. Here, next to the speed of the transition, stakeholders are concerned with how inclusive the process will be, and participation and transparency become anchors for a sustainable and inclusive transition.

Future interdisciplinary research should focus on interrelations between flexibility, storage, social practices and related environmental impacts and natural resource use to help clarify inclusive pathways for cleaner energy production and consumption. Issues of equality are still understudied in new energy systems, particularly the role of women and the opportunities for the participation of more vulnerable communities in distributed energy systems, and how these communities can be disproportionately affected by new centralized investments (e.g., large solar plants), requiring the use of massive rural areas that are vital for local livelihoods. Also, the environmental impacts and resource demand of the energy transition are not yet fully understood, with policies narrowing environmental targets to the reduction of emissions and lacking acknowledgment of transversal issues like externalization.

As the mining of lithium and other minerals becomes widespread across Europe it is critical to understand the broader socio-technical and environmental consequences, potentially creating bottlenecks for a fast transition. It is equally relevant to realize how multiple actors can come together in new governance arrangements, built on democratic participation, and open information systems, that effectively involve citizens, including those most affected by new energy system configurations. Here, citizen assemblies and the role of local governments are an important opportunity for participation and transparency in transition processes.

Funding

The SEEDS project is supported by the CHIST-ERA grant CHIST-ERA-19-CES-004, the Fundação para a Ciência e Tecnologia (FCT) grant number CHIST-ERA/0005/2019, the Estonian Research Council grant number 4-8/20/26. FCT funding includes also the first author's post-doc contract (2020.01663. CEECIND).

Credit author statement

Inês Campos: was responsible for designing the Methodology, the structure of the survey form and of the stakeholder workshop. Facilitated the workshop. Developed the quantitative (survey) and qualitative (workshop) data Formal analysis. She has also structured and written the article. Miguel Brito: was responsible for designing the Methodology, collaborated in designing the structure of the survey form and of the workshop. Collaborated in implementing the workshop and in writing the article. Debora De Souza: Formal analysis was responsible for conducting the exploratory interviews and analysing the interview results. She has also collaborated in writing the article. Aías Santino: collaborated in designing the survey form, structured the stakeholder identification, collected survey responses, collaborated in the design of the workshop. Guilherme Luz: collaborated in the design of the overall Methodology, also in the structure and implementation of the stakeholder workshop, including data collection and Formal analysis. David Pera: collaborated in the structure and implementation of the stakeholder workshop, including data collection and Formal analysis.

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.

Acknowledgements

The authors acknowledge and thank the participation of all stakeholders in this study, who answered the survey and attended our workshop.

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