

Response to the comments made by the reviewers.

In the following, we respond to the individual comments and suggestions made by the three reviewers. The changes we made to the manuscript are either shown (in blue, or if only partially edited, edits are underscored) or, if extensive, referred to.

Comments by reviewer # 1, M Bürgi,

#	Comment	Response
1	The authors present a study on the development of renewable energy project in Portugal. It provides a rich picture and largely well-presented picture of the spatial-temporal development. It is indeed quite revealing to see how in different periods different project types were especially popular and what the reasons for the changes in the preferred project types were	Thank you very much for your thorough and constructive review, and the valuable feedback.
2	1. As such, it is largely descriptive, which is not a criticism, but rather an encouragement not to try to make something else out of the material. Already the very first sentence in the abstract, but also throughout the text (see my comments in the pdf file), I find statements or claims which would require a much more analytical approach. Thus, tuning down this wording to be closer to what the study is indeed able to deliver, would in my view be advisable.	Many thanks for pointing this out. We have toned down the wording where pointed to and further fully reviewed the manuscript to correct any misplaced causal wording throughout. For example: “The expansion of solar and wind power creates complex "energy-land systems" defined by interactions between governance, land use, and energy production. While critical for the energy transition, <u>some utility-scale projects face social contestation, particularly when they are located in marginal rural areas. To support a fair and inclusive national dialogue on the energy transition, a detailed, geographically nuanced understanding of renewable energy systems and their local contexts is required</u> ”, Line 5-8 “Our findings reveal that geography and scale are <u>main elements</u> of energy-land system diversity”, Line 12
3	2. Of course, such an analysis is heavily restricted by data availability. However, some core aspects of renewable	We fully agree on the importance of identifying the developers and investors financing these projects. We initially considered including this aspect, but ownership structures are often masked behind companies created

	energy production are missing and are not even addressed as missing. What I foremost miss is an adequate inclusion of the question of developers and investors: who is finally financially profiting from these projects? I assume that information on this would also be available – why has it not been integrated in the analysis? Neglecting these dimensions comes across as rather naïve, given the well documented power constellations.	for specific projects, requiring deeper corporate data to analyse shareholders. Nevertheless, we agree that omitting such a fundamental aspect of the energy transition might appear naïve. We have now expanded our discussion in the limitations and future research sections to explicitly address this context. Limitations paragraph: “Specific dimensions of our ELS framework, for example concerning type of actors owning, initiating and profiting financially from projects, remained limited due to data access limitations at this scale.”, Line 557-559 Future research paragraph: “Future work can leverage on such typologies to understand how specific policy measures influence trends in ELS, what location factors drive project siting, <u>how ownership and investment structures shape project configurations, and how their material social, ecological, and economic (cumulative) impacts, including the distribution of benefits and burdens, are experienced by affected communities.</u>”, Line 573-576
4	3. Information is provided on the placement of the projects in protected areas – but here, the discussion is developed in a way that largely ignores the reasons why these areas have been designated as protected (such as ecological value, biodiversity, rare species etc). Rather, protected area designation is foremost treated as limiting the potential for land use changes, which lowers the price of the land. Of course, this is very true, but there is a reason for that, i.e., the ecological value of this area. The obvious, but not addressed question is, what these projects (including	We thank the reviewer for this comment, and agree that it is important to highlight that protected areas in this context are not only limiting factors for project establishment, but can represent conflict with environmental protection. We have added this to our discussion: “For wind energy land systems, their occurrence in protected areas and communal lands, <u>and consequently their impacts on ecological and culturally sensitive areas, is underscored by contexts of multiple land-governance regimes</u>, often necessitating biodiversity compensation or co-location with communal grazing activities.”, Line 407-409 “Large utility-scale ELS or those situated in protected areas, communal lands or areas with conservation elements incorporate more <u>documented</u> socio-ecological measures. <u>In the case of large projects in protected areas, such compensation or mitigation schemes respond to their anticipated impacts on biodiversity.</u>”, Line 482-485

	infrastructure necessary to build and maintain the plant, but also power lines, etc.) do to the landscape and biodiversity, looking into the question if these effects are in line with the protection status and aims.	
5	4. The question of just transformation is addressed, but in a rather superficial way, without e.g., mentioning the different dimensions of environmental justice, which could also have led to further differentiations in the coding of the material.	Thank you for this comment. We agree that explicitly addressing justice dimensions strengthens our argument for a just transition. We have now more clearly articulated how different dimensions of environmental justice relate with our approach in our Introduction and Discussion sections. While environmental justice is not the primary analytical framework of our study, we map our approach onto these dimensions across these sections to highlight how our findings engage can contribute to this body of work. In the introduction: <u>“Social acceptance is a complex concept that is tied to energy justice (Batel, 2020), within which two aspects are most relevant: 1) project characteristics (e.g., size, ownership, compensation, local community participation) and 2) the socio-ecological contexts of deployment (Campos et al., 2023; Cousse, 2021; Enserink et al., 2022; Roddis et al., 2020). Because most utility-scale projects are sited in rural landscapes, due to land availability and grid capacity, rural populations are often disproportionately burdened (Brown et al., 2024; Naumann and Rudolph, 2025). This uneven distribution of impacts has led to "green sacrifice zones" in marginalized areas, highlighting the risks of an unjust energy transition (Scott and Smith, 2017; Wallace et al., 2025; Zografos and Robbins, 2020). These interconnected project characteristics and deployment contexts are relevant to, yet not fully capturing, three core dimensions of energy justice: 1) distributive justice (e.g. who bears the benefits and burdens of the energy transition), 2) procedural justice (e.g. the degree to which local communities meaningfully participate in project design and decision-making), and 3)</u>

	<u>recognitional justice (e.g. ensuring projects adapt to local socio-ecological contexts and provide adequate, context-sensitive compensation) (Wijsman et al., 2026).”</u> Line 58-70 In the discussion section 4.4.: “Applying an energy justice lens problematizes themes that could be better addressed by policy and regulation. On distributive justice, a spatial lens reveals how more marginalized rural landscapes disproportionately bear larger and potentially more impactful projects. Such imbalances in ELS have the potential to foster a perception of geographic and energy injustice that can fuel local resistance and erode trust in the energy transition (Kebinski, 2026; Krüger, 2022; Mamonova and Franquesa, 2020; Sovacool et al., 2025). On procedural justice, our ELS approach highlights that, while projects document distinct levels of transparency and participation, most utility-scale ELS include very low levels of procedural engagement. In a context of accelerated permitting processes, there is a need for clear mandates for transparency, early and meaningful engagement, and demonstrable community influence over project design and decision-making (Boudet et al., 2025; ICLEA, 2025) (Boudet et al., 2025; Loomis et al., 2022). On recognitional justice, a land-system approach demands a place-based analysis to highlight how projects might adapt to local conditions, including levels of socio-ecological marginalization, through socio-ecological measures and co-location with other land uses. Nevertheless, the extent to which project recognizes local identities, knowledge, vulnerabilities, attachment to place, or culturally significant land relations in project design and decision-making remains unclear. Despite observed instances of more context-specific planning, rising social opposition raises critical questions: to what standards are we upholding RE projects, and through which energy models can those standards be met? Incentives, such as feed-in tariffs or low-interest loans, can be designed to mobilize a wider network of actors as agents in the energy transition. Such incentives could support innovative production models (e.g., battery storage and agrivoltaics providing additional income sources for farmers (Ali Khan Niazi
--	--

		and Victoria, 2023)), self-consumption, and energy communities. Utility scales projects could move away from financial compensation schemes towards financial participation.”, Lines 525-546
6	5. Thus, the data presented is indeed revealing interesting pattern. I overall suggest to (I) more adequately address the financial, ecological and justice aspects of renewable energy projects, (II) add some information necessary to document the analysis better (e.g., missing information on the variables used as “socio-ecological marginalization variables”: what does the “renovation index” stand for?) and (III) clarify some of the rather vague or even confusing statements on relevance of the study.	Many thanks for this summary of main issues: we have now more thoroughly addressed the financial, ecological and justice aspects of these energy land systems, see response to comments 3,4 and 5. We have added information on the variables used as socio-ecological marginalization, in Table 2. Here we also clarify the now active population index variable. Finally, we have reviewed the full manuscript to avoid any statement that might be vague, confusing on the relevance of our results. For example: <u>“By being co-located with other land uses and involving a diverse array of actors and energy systems, decentralized ELS exhibit a more multifunctional character than utility-scale systems though their embeddedness within the urban landscape. Typically found in urban settings, they take advantage of the considerable solar PV generation potential in the built environment and bring production closer to demand. This trend is reflected by their higher presence in the North and Centre regions of Portugal (Kakoulaki et al., 2026). Decentralized ELS benefit from a wider constellation of involved actors that can reap the benefits of the energy transition, if the governance and financing arrangements of projects allow broad ownership, democratic control, accessibility, and/or benefit-sharing (Ferreira, 2025). Therefore, these systems are located in less socially marginalized contexts compared to the other ELS. These contexts are characterized by high healthcare accessibility, high average income, and greater population density. Renewable energy production is embedded within the urban landscape; rather than replacing existing land uses, it is co-located with them. Geographically, decentralized projects show a dispersed distribution with a high focus on the North and Centre regions of Portugal, despite the best solar</u>

		~~conditions being in the south (Cavaco et al., 2016). This might be explained by higher infrastructure suitability for rooftop solar, higher population density, and predominance of industrial activities (Kakoulaki et al., 2026).~~ ”, Line 431 - 438										
7	Comments on all these aspects can be found directly in the pdf attached. <table><tr><th>Main criteria</th><th>Score</th></tr><tr><td>Originality (novelty)</td><td>2</td></tr><tr><td>Scientific quality (rigour)</td><td>2-3</td></tr><tr><td>Significance (impact)</td><td>2</td></tr><tr><td>Presentation quality</td><td>2</td></tr></table> Excellent (1), Good (2), Fair (3), Poor (4)	Main criteria	Score	Originality (novelty)	2	Scientific quality (rigour)	2-3	Significance (impact)	2	Presentation quality	2	We thank the reviewer for their positive evaluation. We hope that by addressing the concerns presented above we improve the general quality of this manuscript.
Main criteria	Score											
Originality (novelty)	2											
Scientific quality (rigour)	2-3											
Significance (impact)	2											
Presentation quality	2											
8	I have troubles following the rationale of this introduction. What for is such an understanding required? And what does "granular" mean in this context? (Line 4-8)	Thank you for this comment, we agree the logical steps here where not clear thus we have made this sentence clearer. Social acceptance can be related on one hand with characteristics of the project and its establishment as well as with the contexts of their establishment. We further simplify here the link of these two dimensions, past project characteristics and context, with future social acceptance of RE projects. <u>“While critical for the energy transition, some utility-scale projects face social contestation, particularly when they are located in marginal rural areas. To support a fair and inclusive national dialogue on the energy transition, a detailed, geographically nuanced understanding of renewable energy systems and their local contexts is required”</u>, Line 5-8										
9	Why is social acceptance linked to the understanding of major types of ELS created at a country scale? (line 53-55)	Thanks for this question, we agree it is an important clarification to be made we include it in our introduction. Histories of ELSs determine past experiences with RE projects both at the decision making level and local communities experience (Boudet et al 2025). Hereby past experiences set permissible										

		scales, frameworks and narratives around RE which inform future social acceptance of projects. “We currently lack an understanding of the major types of ELS created at a country scale. <u>Such understanding could reveal former decision-making processes, local communities’ experiences and landscape outcomes, which all have implications for social acceptance (Boudet et al. 2025).</u>”, Line 55-57
10	In what respect does the paper live up to the claim of addressing local needs? (Line 97-99)	Thank you for this comment, our reasoning was arguing for context specificity would support local need, however we acknowledge that addressing local needs requires a more detailed understanding of contexts and thus we have soften this claim on how ELSs adapt to wider local contexts. “The <u>objective of this study is to look back at RE developments in Portugal with high granularity to identify the major ELS created and assess whether and how they generate co-benefits, adapt to local contexts, and support multifunctional landscapes</u>” Lines 107-109
11	How does this relate to "urbanization level" introduced in the chapter before? If the aspect here is about marginalization, should you not rather look into the e.g., changes in the last decades? Couldn't it be, that "very low density rural" is not a result of marginalization, but was never less rural in the first place? (Line 211-212)	Many thanks for this comment; we agree this is an important distinction. The term 'very low density rural' was a remnant of a variable we initially used to classify urbanization. This was an oversight on our part, as we ultimately adopted the urbanization framework from Wolf et al. (2020). We have updated the text to replace this example with a socio-ecological marginalization variable. “We used non-parametric Wilcoxon Rank-Sum Test for the continuous and categorical variables after reclassifying categorical variables to ordinal values (e.g., from "very degraded" = '1' to "overperformance" = '6').”, Lines 222-223 The Wolf et al. dataset—which we simplified into 'rural', 'urban', and 'urbanization'—identifies areas experiencing rural decline, which applies to all parishes within our simplified 'rural' category. We have clarified this in our analysis by aligning our classification directly with the original framework by Wolf et al.

		“We presented the spatial distribution of ELS types by Portuguese regions (NUTII) and overlaid types on an adapted map of urbanisation levels (Wolf et al., 2020). These levels were simplified into three categories: <u>rural decline (rural areas with population decline)</u>, <u>stable urban (urban areas with stable population)</u>, and <u>urbanization (areas in rural or peripheries of urban areas that have experienced growth in population density and services).</u>”, Lines 208-212
12	Information on these is partially provided in the last methods chapter, but e.g., the rather mysterious "Renovation index" seems not to be explained anywhere. And this information should in my view be part of the main text, i.e., one can not only refer to SI. (Line 340)	We have added information on the variables used as socio-ecological marginalization in Table 2. Here we also clarify the renovation index variable and change it to active population index, which refers the ratio between the population potentially entering the labour market (ages 20–29) and those potentially exiting (ages 55–64) (INE, 2024a). It indicates the capacity of a population to replace its workforce at the municipality level.
13	This does not come as a surprise. (Line 350-351)	We agree this sentence is not surprising. However, it remains an important distinction, thus respectfully we keep it. Nevertheless, we have reviewed the entire section to remove remaining trivial discussion points.
14	I do find the combination of variables referring to a state (e.g., healthcare access) with variables referring to a process (depopulation) not ideal. Would it not have made more sense to distinguish between low population areas and areas showing a decline in population in the last decades? See also my comment on urban/rural above. (line 380-381)	Indeed, the use of the urbanization variable refers to a process-based variable showing this decline (see response to comment 11), while the population density refers to static evaluation. We make this clearer in our analysis and results.
15	Is this the right term here? I appears to me that these areas were not reserved for wind, but were simply preferred areas for wind projects. (line 399)	We agree, have now changed to “preferred”.
16	Some of these statements are rather trivial and are repeated in one way or the other too many times: with less population you have less houses, i.e.,	We have reformulated this section to avoid any inessential/trivial statements.

	the potential for rooftop solar, decentralized projects is simply higher etcetc. I strongly suggest to focus the discussion on the non-trivial findings. (line 409-411)	For example: <u>“By being co-located with other land uses and involving a diverse array of actors and energy systems, decentralized ELS exhibit a more multifunctional character than utility-scale systems ~~though their embeddeness within the urban landscape~~. Typically found in urban settings, they take advantage of the considerable solar PV generation potential in the built environment and bring production closer to demand. This trend is reflected by their higher presence in the North and Centre regions of Portugal (Kakoulaki et al., 2026). Decentralized ELS benefit from a wider constellation of involved actors that can reap the benefits of the energy transition, if the governance and financing arrangements of projects allow broad ownership, democratic control, accessibility, and/or benefit-sharing (Ferreira, 2025). Therefore, these systems are located in less socially marginalized contexts compared to the other ELS. These contexts are characterized by high healthcare accessibility, high average income, and greater population density. Renewable energy production is embedded within the urban landscape; rather than replacing existing land uses, it is co-located with them. Geographically, decentralized projects show a dispersed distribution with a high focus on the North and Centre regions of Portugal, despite the best solar conditions being in the south (Cavaco et al., 2016). This might be explained by higher infrastructure suitability for rooftop solar, higher population density, and predominance of industrial activities (Kakoulaki et al., 2026).”, Line 431 - 438</u> <u>“This evolution is reflected in both the number of projects and their respective accumulated capacities. While small scale wind ELS still represent the majority of projects and of accumulated capacity for the wind sector, the solar sector displays a different pattern. Although small-scale solar projects are more numerous, "very large-scale" solar ELS provide the highest share of capacity (2.2 GW in 2025).”, Lines 471-472</u>
17	This statement latest underlines how important it also is to look into questions of ownership of the	We agree on the importance of including the dimension of actors in a more detailed form as they would likely

	projects and corporate/financial structure: who owned the land before? who initiated the project? who profits from the project also financially? Are there a few large companies running the show or are there very different and diverse players around? I miss data, or at least some reflections on this aspect. (line 450-451)	entail different power relations, we have added to our discussion and limitations and future research a reflection on this. See also response to comment 3. Section 4.4 of the discussion: <u>“Despite observed instances of more context-specific planning, rising social opposition raises critical questions: to what standards are we upholding RE projects, and through which energy models can those standards be met?”</u> Incentives, such as feed-in tariffs or low-interest loans, can be designed to mobilize a wider network of actors as agents in the energy transition. Such incentives could support innovative production models (e.g., battery storage and agrivoltaics providing additional income sources for farmers (Ali Khan Niazi and Victoria, 2023)), self-consumption, and energy communities. Utility scales projects could move away from financial compensation schemes towards financial participation.”, Line 539-546 Limitations paragraph: “Specific dimensions of our ELS framework, for example concerning type of actors owning, initiating and profiting financially from projects, remained limited due to data access limitations at this scale.”, Line 557-559 Future research paragraph: “Future work can leverage on such typologies to understand how specific policy measures influence trends in ELS, what location factors drive project siting, <u>how ownership and investment structures shape project configurations, and how their material social, ecological, and economic (cumulative) impacts, including the distribution of benefits and burdens, are experienced by affected communities.</u>”, Line 573-576
18	This wording makes it almost sound as if placing such project in protected area would be the thing to do.... there are of course reasons, why such projects require higher levels of participation etc., they are most likely obliged to do this and at the same time they most likely have negative impacts on such protected areas. Of course, not all e.g. solar project must be negative for biodiversity, but I	Thank you for pointing this out; we agree that the original wording was unclear. We have revised the text to clarify that compensation measures in protected areas are designed to offset negative externalities affecting the biodiversity and ecosystems that these areas are established to protect. See response to comment 4. <u>“Large utility-scale ELS or those situated in protected areas, communal lands or areas with conservation elements incorporate more documented socio-ecological</u>

	guess this is hardly documented for projects within the perimeter of protected areas. (line 463-464)	measures. <u>In the case of large projects in protected areas, such compensation or mitigation schemes respond to their anticipated impacts on biodiversity.</u> ”, Line 482-485
19	Very true. But building a solar plant in them might still raise some questions, considering exactly these environmental protection regulations! There is usually a reason for those, they are not just a nuisance to the land owners! (line 472-473)	Thank you for raising this point. We have removed the explicit mention of environmental regulation here, as lower land prices can result from various factors beyond regulatory land-use restrictions. Together with our responses to comments 4 and 18, we believe it is now clear that protected areas represent more than just a restriction on renewable energy projects. “(iii) renting or acquiring large contiguous land parcels is often easier in regions where economic activity and land prices are low, ~~e.g. due to land-use limitations imposed by environmental protection regulations.~~”, Line 492-493

Comments by reviewer # 2, P. Blechinger,

#	Comment	Response
1	1. Summary of the manuscript This work analyses the characteristics of energy-land systems (ELS) in Portugal. A total of 760 individual systems and projects are clustered into 18 groups to enable comparison between them. For each group, several dimensions are tested, leading to a number of conclusions — for example, that wind generation is concentrated in the north, and that utility-scale PV tends to be located in less wealthy areas compared with decentralised PV. Overall, the paper presents a very interesting inventory of renewable energy projects in Portugal.	Thank you for the kind words and the structured and helpful feedback.

2	2. Constructive critique — by section Abstract • Strengths: The abstract is clearly written and follows a good storyline. •	Thank you
3	• Weaknesses / deficiencies (with reasoning): The abstract overclaims somewhat, as not all of the stated conclusions can be clearly derived from the data. The analysis reads more as descriptive work than as a statistically robust or causal analysis, and the abstract should reflect this more accurately. • Specific improvements needed: Moderate the tone and avoid overstating the results, framing the findings as descriptive rather than causal where appropriate.	Many thanks for this constructive comment, we have reviewed to abstract to remove any potential overclaims. “The expansion of solar and wind power creates complex "energy-land systems" defined by interactions between governance, land use, and energy production. While critical for the energy transition, <u>some utility-scale projects face social contestation, particularly when they are located in marginal rural areas. To support a fair and inclusive national dialogue on the energy transition, a detailed, geographically nuanced understanding of renewable energy systems and their local contexts is required.</u> Focusing on Portugal, we categorized 760 renewable energy projects and used multivariate cluster analysis to identify 18 energy-land system types. Deployment contexts were analysed using indicators of socio-ecological marginalization, including land degradation, energy poverty, income levels, demographic dynamics, and land prices. Our findings reveal that geography and scale are <u>main elements</u> of energy-land system diversity. Wind systems in the North <u>include more</u> co-location (e.g., pasture, beekeeping) and co-governance (e.g., protected areas, commons), while solar systems in the South are distinguished by production levels and externality mitigation.” Lines 4-15
4	Introduction • Strengths: The introduction explains well why social dimensions matter for the energy transition. It moves from the broad context to the specific problem, as is good practice: climate change requires more	Thank you

	renewable energy, renewable energy requires land, and this is becoming an increasingly important issue. The authors make the case that planning should incorporate more dimensions than grid access and technically available land alone.	
5	Weaknesses / deficiencies (with reasoning): The introduction sets out a clear problem to be solved — namely, the need for a siting approach that better links the type of project to its specific socio-ecological context, in order to deliver multiple benefits and support both climate targets and a just energy transition. However, the paper does not actually provide solutions to this problem.	Thank you for this point. We agree that we can more clearly articulate what the manuscript contributes to. We have reformulated various points in the introduction and discussion to highlight this shift. We now more explicitly articulate how understanding project characteristic and socio-ecological contexts can contribute to more nuanced understanding of the RE transition and further link with dimensions of justice (see response to comment 5, 9 and 10, of Reviewer 1) <u>“We currently lack an understanding of the major types of ELS created at a country scale. Such understanding could reveal former decision-making processes, local communities’ experiences and landscape outcomes, which all have implications for social acceptance (Boudet et al. 2025).”</u> Lines 55-57 In the introduction: <u>“Social acceptance is a complex concept that is tied to energy justice (Batel, 2020), within which two aspects are most relevant: 1) project characteristics (e.g., size, ownership, compensation, local community participation) and 2) the socio-ecological contexts of deployment (Campos et al., 2023; Cousse, 2021; Enserink et al., 2022; Roddis et al., 2020). Because most utility-scale projects are sited in rural landscapes, due to land availability and grid capacity, rural populations are often disproportionately burdened (Brown et al., 2024; Naumann and Rudolph, 2025). This uneven distribution of impacts has led to "green sacrifice zones" in marginalized areas, highlighting the risks of an unjust energy transition</u>

		(Scott and Smith, 2017; Wallace et al., 2025; Zografos and Robbins, 2020). <u>These interconnected project characteristics and deployment contexts are relevant to, yet not fully capturing, three core dimensions of energy justice: 1) distributive justice (e.g. who bears the benefits and burdens of the energy transition), 2) procedural justice (e.g. the degree to which local communities meaningfully participate in project design and decision-making), and 3) recognitional justice (e.g. ensuring projects adapt to local socio-ecological contexts and provide adequate, context-sensitive compensation) (Wijsman et al., 2026).</u>” Line 58-70 “Therefore, there is a need for understanding the links between types of project and specific socio-ecological contexts. Understanding the state of context-specific approaches can help us problematize not only how climate targets are achieved but also in what ways do they also promote a just energy transition.”, Lines 81-84 “The <u>objective of this study is to look back at RE developments in Portugal with high granularity to identify the major ELS created and assess whether and how they generate co-benefits, adapt to local contexts, and support multifunctional landscapes</u>” Lines 107-109
6	Specific improvements needed: The problem statement should be more closely linked to the actual research work and the research questions, which are good. The choice of Portugal as a case study currently seems somewhat arbitrary and should be better embedded in the storyline.	Regarding the connection between the problem statement and research questions, please see our response to comment 5 above. Regarding the selection of Portugal as our case study, we have added an opening sentence explaining the key reasons for this choice “We selected Portugal as a case-study given its high RE uptake, ambitious legislative targets, and growing social contestation surrounding RE developments.”, Lines 84-85
7	Methods	Thank you

	Strengths: The paper uses a wide variety of methods, including tests of their validity.	
8	- Weaknesses / deficiencies (with reasoning): The completeness of the project database is not stated (for example, in comparison with total installed capacity). In particular, the number of small-scale decentralised PV projects is very low compared with the number of real installations — a quick search suggests roughly 120,000 systems — which raises the question of how representative the data can be. In addition, the methods section reads more as a narrative account of what was done, step by step, than as a justification of the chosen approach and the selection of methods. - Specific improvements needed: Revisit the small-scale PV data. Revise the text to focus on why each step was taken rather than simply how.	This study focuses on a small sample of decentralized projects to enable a multidimensional categorization. We acknowledge that the representativeness of this data is difficult to access given limitation on data availability and thus this data only serves to categorize typologies. To analyse distribution, we included the full data with a limited set of information on decentralized systems (sourced from E-redes). We have added a clarification in the methods and in the discussion of the limitations. In the methods section: “To capture the decentralized RE segment, we collected information on individual projects from different platforms and company websites (e.g., GoParity) and from previous studies on collective energy projects (Ferreira, 2025). We also requested data from energy companies and energy cooperatives, with only one response received. Finally, we generated dummy projects classified as typical personal solar panels (below 6 kW) to include a sample of individual self-consumption projects following the Portuguese distribution system operator (DSO) categorization. <u>This allowed building a representative sample of decentralized projects that were characterized in detail. However, to understand the spatial dimension of decentralized projects, we used the aggregated data on self-consumption and collective self-consumption projects available from the Portuguese DSO data platform, representing all connected decentralized projects (E-REDES, 2025b, a).</u>” Lines 152-161 In the Limitations section: “Furthermore, for decentralized projects, we relied on a representative sample due to the limited data availability <u>that allowed for a characterization of projects.</u>”, Lines 559-561 Furthermore, on the completeness of our database, we include a comparison of reported total installed capacity for

		utility scale and total installed capacity included in our analysis. The values are quite comparable (9302 MW in deployed projects in our analysis to 9661 MW officially reported), thus we believe we have a close to complete database. “Overall, deployed utility-scale projects in our analysis total 9302 MW of installed capacity, compared to 9661 MW reported at the end of 2025 (DGEG, 2025b)”, Line 307-308
9	Results Strengths: The inventory is very good, the clusters are interesting, and Sections 3.1 and 3.2 contain a great deal of information that is valuable in its own right. Section 3.3 adds a further level of insight by comparing the social and ecological characteristics of the plants.	Many thanks for your positive remarks.
10	Weaknesses / deficiencies (with reasoning): The study remains descriptive, even though some statements are phrased as though they establish causal relationships	We have reviewed our manuscript to remove any causal wording, please see below examples in our results section. We kept references to statistically significant associations with socio-ecological marginalization variables. For example: “At a more detailed level, wind ELS ~~are predominantly distinguished~~ <u>differ</u> by their co-location with other land uses, co-governance systems, public participation, transparency and types of compensation” Lines 240-242 “This trajectory culminated in 2022–2023 with the ~~commissioning arrival~~ <u>arrival</u> of very large-scale systems. More recent periods also include the emergence of hybrid wind–solar and floating PV configurations, ~~resulting in more complex landscapes.~~” Lines 324-326
11	Specific improvements needed: Take care not to overinterpret the data, and focus on describing	We have removed any identified instance of interpretation of results from our results section, see response to your comment 10. We took in consideration this suggestion into our discussion section where we try to ensure a clear

	patterns. As an optional addition, the “why” behind some observations — for example, why decentralised ELS are generally found in less socially marginalised contexts than utility-scale ELS — could be explored through an additional literature review or expert interviews. This would add significant value, though it may be beyond the scope of the present work.	distinction between empirical results and their interpretation, we have removed causal language from the results and discussions section and made sure our explanatory hypotheses in the discussion are supported by relevant references. Regarding why decentralized are generally found in less socially marginalised contexts than utility-scale ELS, we have removed this section of the discussion in response to comment 6 and 16 from reviewer 1.
12	Discussion Strengths: The discussion picks up the results and begins to interpret them well.	Thank you
13	Weaknesses / deficiencies (with reasoning): It is quite long and repeats some of the results.	Thank you, we have reviewed the discussion to remove any trivial (see comment 6 and 16 to R1) and repetition. <u>“By being co-located with other land uses and involving a diverse array of actors and energy systems, decentralized ELS exhibit a more multifunctional character than utility-scale systems ~~though their embeddeness within the urban landscape~~. Typically found in urban settings, they take advantage of the considerable solar PV generation potential in the built environment and bring production closer to demand. This trend is reflected by their higher presence in the North and Centre regions of Portugal (Kakoulaki et al., 2026). Decentralized ELS benefit from a wider constellation of involved actors that can reap the benefits of the energy transition, if the governance and financing arrangements of projects allow broad ownership, democratic control, accessibility, and/or benefit-sharing (Ferreira, 2025). Therefore, these systems are located in less socially marginalized contexts compared to the other ELS. These contexts are characterized by high healthcare accessibility, high</u>

		average income, and greater population density. Renewable energy production is embedded within the urban landscape; rather than replacing existing land uses, it is co-located with them. Geographically, decentralized projects show a dispersed distribution with a high focus on the North and Centre regions of Portugal, despite the best solar conditions being in the south (Cavaco et al., 2016). This might be explained by higher infrastructure suitability for rooftop solar, higher population density, and predominance of industrial activities (Kakoulaki et al., 2026).”, Line 431 - 438
14	Specific improvements needed: Focus on one main statement per sub-chapter. First state the claim based on the descriptive data, then interpret it and explain why you think the results look as they do (this is the appropriate place for such reasoning, rather than the conclusions), and finally test the claim against other studies — especially in Section 4.4.	Thank you very much for this helpful suggestion. We have followed your recommendations as closely as possible and revised the discussion section to sharpen our main messages and better ground them in current literature. Specifically, the discussion is more clearly structured into four sections: 1. Our findings on geographies of wind versus solar energy types; 2. Decentralization and diversity of actors; 3. Large- versus small-scale energy systems (ELS) trade-offs; 4. Our work’s potential contribution to a just energy transition, explicitly linking our results to established literature on energy justice dimensions (see also our response to Comment 5 from Reviewer 1). Additionally, we now refer to the possibility of adapting our framework to better analyze energy system models, which are increasingly—though still partially—incorporating social dimensions. “Given sufficient project data, this approach can be adapted to other regions and customized, through targeted variable selection, to address specific research or planning needs, such as supporting advances in energy-planning

		models that incorporate social elements (Codemo et al., 2023, 2024; Krumm et al., 2022).”, Lines 570-572
15	Conclusions • Strengths: — • Weaknesses / deficiencies (with reasoning): The conclusions overinterpret the results and draw too many social and just-transition claims that are not supported by the results presented. • Specific improvements needed: Keep the conclusions simpler and more closely aligned with the results section. Focus instead on how the data can be used for the future planning and siting of renewable energy projects.	We have reformulated the conclusion to follow more closely our results section, focusing on how this analysis can contribute to the future planning and siting of renewable energy projects. For example: “Beyond the Portuguese case, the typology of energy-land systems developed in this study offers a transferable analytical lens examining how different energy-project configurations materialize across landscapes in different national contexts. Further assessment of ownership, benefit-sharing, participation, cumulative impacts, and the recognition of local and ecological values is required to determine whether particular ELS contribute to a spatially just energy transition ~~that ensures a just transition that aligns energy production with rural revitalization and equitable distribution of energy systems benefits. In such context, energy governance could, among other measures, prioritize co-designing the energy transition, administrative simplification for energy communities, incentivize agrivoltaics to preserve agricultural capacity, and integrate social and participation metrics into capacity auctions.~~ Nevertheless, such knowledge can inform more nuanced, place-based energy governance, supporting the navigation of trade-offs between scale, location, design, agents, and governance. This information should support a multi-stakeholder decision process whose aim is to shape an energy landscape that is not only carbon-neutral but also socio-ecologically resilient and spatially just.”. Line 595-603)
16	3. Detailed considerations • Does the title clearly reflect the contents? Yes. • Does the abstract provide a concise and complete summary? Yes, with some improvements needed (see above).	Thank you for your positive remarks. Many thanks for this constructive comment, we have reviewed to abstract to remove any potential overclaims. See response to comment 3. For example: “The expansion of solar and wind power creates complex "energy-land systems" defined by interactions between governance, land use, and energy production. While

		critical for the energy transition, <u>some utility-scale projects face social contestation, particularly when they are located in marginal rural areas. To support a fair and inclusive national dialogue on the energy transition, a detailed, geographically nuanced understanding of renewable energy systems and their local contexts is required</u>". Line 4-8 "Our findings reveal that geography and scale are <u>main elements</u> of energy-land system diversity", Line 12
17	• Is proper credit given to related work, with the authors' own contribution clearly indicated? Yes. The research gap is clear and is addressed by a new methodological framework and new data. • Does the paper address relevant scientific questions within the scope of Land Systems? Yes. • Are methods and assumptions valid and clearly outlined? Partly (see above). • Are experiments/calculations described precisely enough to be reproduced? Yes.	Thank you for your positive remarks. Regarding the methods and assumptions, we have provided further clarification on the limitations associated with the decentralized sample. Additionally, we have detailed our approach to assessing distribution using the comprehensive yet coarsely descriptive dataset from the DSO. Please refer to our response to comment 8. In the methods section: <u>"To capture the decentralized RE segment, we collected information on individual projects from different platforms and company websites (e.g., GoParity) and from previous studies on collective energy projects (Ferreira, 2025). We also requested data from energy companies and energy cooperatives, with only one response received. Finally, we generated dummy projects classified as typical personal solar panels (below 6 kW) to include a sample of individual self-consumption projects following the Portuguese distribution system operator (DSO) categorization. This allowed building a representative sample of decentralized projects that were characterized in detail. However, to understand the spatial dimension of decentralized projects, we used the aggregated data on self-consumption and collective self-consumption projects available from the Portuguese DSO data platform, representing all connected decentralized projects (E-REDES, 2025b, a)." Lines 152-161</u> In the Limitations section: <u>"Furthermore, for decentralized projects, we relied on a representative sample due to the limited data availability</u>

		that allowed for a characterization of projects.” , Lines 559-561
18	• Are the results sufficient to support the interpretations and conclusions? No. The conclusions are not fully justified by the data and the approach (see above). • Are substantial conclusions reached? Partly (see above).	We have made effort to clarify our core conclusions and better contextualized our findings. Additionally, we have revised sections of our discussion to highlight the added value of our approach more clearly. Finally, the conclusion has also been updated to align directly with the results, highlighting how this analysis can inform future renewable energy planning and siting. For example: In the discussion: “Applying an energy justice lens problematizes themes that could be better addressed by policy and regulation. On distributive justice, a spatial lens reveals how more marginalized rural landscapes disproportionately bear larger and potentially more impactful projects. Such imbalances in ELS have the potential to foster a perception of geographic and energy injustice that can fuel local resistance and erode trust in the energy transition (Kebinski, 2026; Krüger, 2022; Mamonova and Franquesa, 2020; Sovacool et al., 2025). On procedural justice, our ELS approach highlights that, while projects document distinct levels of transparency and participation, most utility-scale ELS include very low levels of procedural engagement. In a context of accelerated permitting processes, there is a need for clear mandates for transparency, early and meaningful engagement, and demonstrable community influence over project design and decision-making (Boudet et al., 2025; ICLEA, 2025) (Boudet et al., 2025; Loomis et al., 2022). On recognition justice, a land-system approach demands a place-based analysis to highlight how projects might adapt to local conditions, including levels of socio-ecological marginalization, through socio-ecological measures and co-location with other land uses. Nevertheless, the extent to which project recognizes local identities, knowledge, vulnerabilities, attachment to place, or culturally significant land relations in project design and decision-making remains unclear. Despite observed instances of more context-specific planning, rising social opposition

		raises critical questions: to what standards are we upholding RE projects, and through which energy models can those standards be met? Incentives, such as feed-in tariffs or low-interest loans, can be designed to mobilize a wider network of actors as agents in the energy transition. Such incentives could support innovative production models (e.g., battery storage and agrivoltaics providing additional income sources for farmers (Ali Khan Niazi and Victoria, 2023)), self-consumption, and energy communities. Utility scales projects could move away from financial compensation schemes towards financial participation.”, Lines 525-546
19	- Are references appropriate in number and quality? The cited literature looks comprehensive and relevant. More credit could be given to energy-planning research and to how this approach could be integrated into planning or even energy-system modelling, for example: - Krumm et al., “Modelling social aspects of the energy transition: What is the current representation of social factors in energy models?” - Hörsch et al., “PyPSA-Eur: An Open Optimisation Model of the European Transmission System” Risch et al., “Potentials of Renewable Energy Sources in Germany and the Influence of Land Use Datasets	We have made efforts to better compare our results to previous research, including energy-planning research and energy-systems modelling. We added a reflection on how our work could be used in energy planning in our section 4.4 Land system science approach to navigating a just energy transition. “Given sufficient project data, this approach can be adapted to other regions and customized, through targeted variable selection, to address specific research or planning needs, such as supporting advances in energy-planning models that incorporate social elements (Codemo et al., 2023, 2024; Krumm et al., 2022).”, Lines 570-572

20	• Is the supplementary material appropriate in amount and quality? Yes. • Is the language fluent and precise? Yes. • Are formulae, symbols, abbreviations, and units correctly defined and used? A few corrections are needed: “Floatvoltaic” should, in my view, be “floating PV”; and in Table 1, “energy production” should not be linked to installed capacity — it would be better termed “renewable capacity”.	We have updated the terminology throughout the manuscript from “Floatvoltaic” to “floating PV” and “energy production” to “renewable capacity”.
21	Should any parts (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? Figure 2: the unit is missing on the y-axis of the upper-left graph. More generally, the x-axis should be labelled in every figure, as some plots currently lack a clear axis label and this makes them harder to interpret.	We have created a new Figure 2 for increased readability of the results, allowing for easy interpretation. Here we include the missing label in the y-axis of the upper left, we also change the colour coding to relate to ELS type, this way we do not repeat the x-axis legend throughout (turning the figure heavy) but still provide a way to guide the reader.
22	4. Recommendation: Major revisions Justification: The paper itself is interesting and of high quality, but it overclaims its results and conclusions, and this needs to be corrected. In addition, the database for small-scale PV appears questionable, which could substantially change the results.	Thank you very much for your constructive feedback. We have made a concerted effort to better clarify the use and limitations of the small-scale PV database, as well as to temper any potential overstatements regarding our results (please see our responses to comments 8 and 17, which we feel have significantly strengthened the manuscript). However, we respectfully disagree that modifications to the small-scale database would substantially alter our primary findings and conclusions. Small-scale PV represents just one component of the broader energy transition, and we have made efforts to ensure our dataset is as comprehensive as possible.
23	5. Reviewer declarations	Thank you for your transparency.

	• Competing interests. I have no interests that might interfere with an objective review of this manuscript. • Competence. I have adequate expertise to provide an authoritative assessment of this manuscript, with a main focus on energy planning. • Peer review assistance. I did not consult anyone for assistance with this review. • Use of AI tools. I have not used AI tools in conducting this review or preparing these comments, aside from grammar, language, and style checking. • I confirm that all comments above are courteous and capable of withstanding public scrutiny, in line with the Interactive Public Peer Review process.		
24	Main criteria	Score (1-4)	Many thanks for this positive scoring. We hope that by addressing the concerns present above we improve the general quality of this manuscript.
	Originality (novelty)	1	
	Scientific quality (rigour)	2	
	Significance (impact)	2	
	Presentation quality	1	
	Excellent (1), Good (2), Fair (3), Poor (4)		

Comments by reviewer # 3 Martin Rudbeck Jepsen,

#	Comment	Response
1	Thanks for allowing me a chance to read this interesting study on energy land systems. My background is in land system science and geography, and I am not an expert on renewable energy systems and their implementation, so this study was enlightening. The study is well written and easy to read and certainly focuses on a land use that could be expected to increase substantially in Portugal, the EU and beyond.	Many thanks.
2	1. I think the manuscript could benefit from clarification of key concepts: - What do you exactly understand by socio-ecological marginalization? - What are decentralized/centralized energy solutions?	Thank you for this comment. We have included in our introduction a clarification for socio-ecological marginalization and decentralized/centralized energy solutions. See here: “We then typified solar and wind land systems based on several indicators and contrast them with proxy variables for social and ecological marginalization of landscapes. These variables are quantitative indicators measuring social disadvantage, low agroecological potential and environmental degradation.”, Lines 111-114 And here: “The vast majority (86%) of this capacity is utility-scale (i.e., large facilities connected to high-voltage transmission networks to transport energy at distance), in the form of wind, solar, and hydropower concentrated in rural areas. The remaining capacity (14%) is based on decentralized solar installations (i.e., feeding local distribution networks, as rooftop installations in residential buildings) (DGEG, 2025b).”, Lines 86-90
3	2. The introduction and discussion touches on equity and justice related to	We have now more clearly articulated with conceptual framework of justice to clarify how we analyse the concepts of equity and justice in a socio-ecological

type and location of ELS. While it is clear that the local population may be burdened by the presence of e.g., PVs, it is less clear how the authors analyse the concepts of equity and justice in a socio-ecological setting? Who and what benefits from ELS, who are burdened? How are ecosystems/habitats/non-human species impacted?	setting. Please also see response to comment 5 of Reviewer 1. In the introduction: “Social acceptance is a complex concept <u>that is tied to energy justice</u> (Batel, 2020), within which two aspects are most relevant: 1) project characteristics (e.g., size, ownership, compensation, local community participation) and 2) the socio-ecological contexts of deployment (Campos et al., 2023; Cousse, 2021; Enserink et al., 2022; Roddis et al., 2020). Because most utility-scale projects are sited in rural landscapes, due to land availability and grid capacity, rural populations are often disproportionately burdened (Brown et al., 2024; Naumann and Rudolph, 2025). This uneven distribution of impacts has led to "green sacrifice zones" in marginalized areas, highlighting the risks of an unjust energy transition (Scott and Smith, 2017; Wallace et al., 2025; Zografos and Robbins, 2020). <u>These interconnected project characteristics and deployment contexts are relevant to, yet not fully capturing, three core dimensions of energy justice: 1) distributive justice (e.g. who bears the benefits and burdens of the energy transition), 2) procedural justice (e.g. the degree to which local communities meaningfully participate in project design and decision-making), and 3) recognitional justice (e.g. ensuring projects adapt to local socio-ecological contexts and provide adequate, context-sensitive compensation) (Wijsman et al., 2026).”</u>, Line 58-70 Regarding who benefits from ELS and who bears the burdens, we can only speculate based on project characteristics and local contexts. Consequently, we refrain from fully exploring these questions, though we highlight them as key areas for future research in our conclusion. Similarly, evaluating how ecosystems, habitats, and non-human species are impacted falls outside the scope of this work. Assessing impact requires distinct methodologies and dataset—such as species distribution overlaps that were inaccessible, or Environmental Impact Assessments (EIAs) that would have restricted our analysis to only a few projects. We agree these are crucial questions and address them in our discussion on future
---	--

		research directions (see below and see also response to comment 3 of reviewer 1) <u>“Future work can leverage on such typologies to understand how specific policy measures influence trends in ELS, what location factors drive project siting, how ownership and investment structures shape project configurations, and how their material social, ecological, and economic (cumulative) impacts, including the distribution of benefits and burdens, are experienced by affected communities.”</u>, Line 573-576
4	3. The fourth research question (how to ELS’ relate to geographies of social and ecological marginalization) could benefit from clarification: what are these geographies theoretically and specifically in a Portuguese context? What do you mean be ‘relate to’?	Thank you for your comment we include in the introduction a clarification of what we meant by social and ecological marginalization. See response to your comment 2 and below. We also expand on what this means in the Portuguese context. <u>“The rapid deployment of utility-scale projects has unfolded against a backdrop of severe socioeconomic challenges in some of Portugal's rural areas, characterized by exodus, with a 20% population decrease over the last 45 years, decaying services, frequent forest fires, land abandonment in some areas, and intensive industrial agriculture development in others (Ferreira et al., 2024; Jones et al., 2011).”</u> Lines 98-102 <u>“We then typified solar and wind land systems based on several indicators and contrast them with proxy variables for social and ecological marginalization of landscapes. These variables are quantitative indicators measuring social disadvantage, low agroecological potential and environmental degradation.”</u>, Lines 111-114 Regarding research question 4, we change it to: <u>“Do different types of energy-land systems overlap with socially and ecologically marginal areas?”</u> Line 116-117
5	4. Finally, there seems to be an underlying assumption that rural exodus is negative (line 77, lines 90-92). I would like to see some arguments for this assumption, preferably for	Many thanks for this comment, we agree that this requires further clarification. Rural exodus is not inherently negative; however, in the Portuguese context, it has been particularly problematic due to the severe aging and shrinking density of rural populations, a point we have now clarified in the introduction please see also response to your comment 4.

	the combined socio-ecological system.	“The rapid deployment of utility-scale projects has unfolded against a backdrop of severe socioeconomic challenges in some of Portugal's rural areas, <u>characterized by exodus, with a 20% population decrease over the last 45 years</u>, decaying services, frequent forest fires, land abandonment in some areas, and intensive industrial agriculture development in others (Ferreira et al., 2024; Jones et al., 2011).” Lines 98-102 This phenomenon has driven diverse geographical processes of landscape marginalization. On the one hand, the abandonment of previously managed lands has encouraged shifts toward lower-maintenance land uses, such as eucalyptus plantations, alongside the intensification of agriculture elsewhere driven by competitive advantages over extensive systems. More critically, the lack of management across vast areas of land has increased vulnerability to catastrophic wildfires, with devastating impacts on landscapes, communities, and non-human species. Nevertheless, we do not wish to imply that this outcome is universal or uniform. For some, rural exodus brings better economic opportunities, and land-use transformations can yield positive outcomes. Therefore, while we now clarify how rural exodus can contribute to marginalization, we are careful not to suggest this is always the case. Finally, to make this clearer, we have shifted our analytical focus from supporting "rural revitalization" to supporting "rural geographies."
6	Specific comments 1. ll. 156 – 159: What did you code? Which information? How was coding structured? Is the codebook and the coded documents made available for transparency?	Thank you for your questions. We have coded sections of the environmental impact assessment report, its evaluation report by the environmental agency, and the final licensing report pertaining to our ELS characterizing variables. We have edited our codebook in SI (Table S2) to clarify any inconsistencies in our coding structure and approach. We will make available the list of projects reviewed with sources of information used upon acceptance in the Dataverse of our university UCLouvain. See examples below of how we made our coding clearer. In the methods section: “We performed a content analysis in Nvivo software (version 14) of the impact assessment report, its

		evaluation report by the environmental agency, and the final permitting report to ascertain ELS variables (SM2, Table S2).”, Line 169-171 Examples in SI Table 2: “Coded examples included agriculture, beekeeping, grazing, agroforestry, which we grouped as “complementary land uses”. “For the small subset of projects assessed using only EIA/EIncA content analysis, we scored the presence of green infrastructure descriptors as 2 and their absence as 1.”
7	2. Table 1: a. I don’t see variables related to marginalized land, land degradation, community socio-economy (e.g., income etc. as a measure of marginalization)? b. Could you add data sources for your variables? c. Should the classification ‘degree’ be ‘ordinal’?	We have now included socio-ecological marginalization variables in Table 2. We include the sources and change “degree” to “ordinal”.
8	3. Figure 1: I see consistency in the subcategories for wind and solar, and partly in decentralized. By why does ‘ground-mounted’ become a subcategory? It is not a variable in table 1, and a very different interpretation of what constitutes a subcategory compared to the other subcategories.	Many thanks for pointing this out. Ground mounted was an intuitive approach to classify a group of ELS characterized by being co-located with built environment. We understand it is not connected with our coding, but we believe however that this the most intuitive wording we could use to classify this type.

9	4. Lines 227-234: This is interesting information – but I don't see it reflected in Figure 1? Could you align the text to the figure?	Thank you for this point we have now reformulated Figure 1 and 2 to improve readability, now this dimensions of differentiation are more clearly shown in Figure 1.
10	5. Lines 256-261: Here, you describe the subcategory Solar utility-scale/small scale, with 100 observations included. However, the text is about a single example. Could you describe what generally characterises the subcategory (besides lacking an EIA)?	Thank for this point we now include a description of this typology. “The “small utility-scale solar” type consists <u>primarily of small solar projects that, given their size and because they do not overlap with protected areas, typically do not undergo an Environmental Impact/Incidence Assessment (EIA/EIncA). Those projects include low proportion of interior and curtain green infrastructure, very low transparency and participation and unidimensional compensation.</u> ” Lines 267 – 271
11	6. Figure 2: the font sizes for legends and axes are too small to read on an A4 print. Please improve readability. Also, the abbreviations used for the clusters should be spelled out in the caption so the reader knows what is what.	Thank you. We have now reformulated Figure 2 to improve readability we believe now the font sizes are readable. We further included any abbreviations to the caption of the figure.
12	7. Table 2: It is difficult for me to read what the difference between cluster 1 and cluster 2 is. Which socio-ecological measures are present in 1 and not in 2? If that differs, what is the general number in 1 and 2? Some transparency would help.	We have removed this table and substitute with an improved figure 1 where the distinctions between types are central.
13	8. Figures 3 and 4: these are nice plots, but as a geographer I can't help thinking that a map of the cluster types would be a nice contribution too!	We have now replaced the geographical related graph (B) in Figure 3 with a map to represent the overall distribution of ELS types.
14	9. Lines 376-381: Here you discuss pros and cons of wind energy land systems. Could you perhaps try to	Thank you for this comment. Following up this and other comments we have rewrote parts of this section to better highlight the contentious relation between wind energy

	reach a synthesis – how does e.g., protected/communal lands and high energy poverty/low productivity landscapes helps us understand the location of ELS better? What are the potential impacts on the local ecology of the ELS (there must be something you have coded in the EIAs)?	land systems preference for remote areas that often coincide with areas of high ecological importance, impacting those ecosystems. “For wind energy land systems, their <u>occurrence in protected areas and communal lands, and consequently their impacts on ecological and culturally sensitive areas, is underscored by contexts of multiple land-governance regimes</u>, often necessitating biodiversity compensation or co-location with communal grazing activities. However, their remoteness also means that utility-scale wind ELS frequently coincide with contexts of high socio-ecological marginalization (<u>which is further discussed in section 4.3</u>)”, Lines 407 - 411 On the relation with marginalization, we discuss this more in depth in the section 4.3. when comparing large versus small projects. “However, these large-scale projects often <u>occur</u> in more marginalized contexts than their smaller counterparts. This may be because: (i) larger projects may only achieve social or regulatory license if the target areas are perceived as not productive, potentially reinforcing the creation of "sacrifice zones"(Dunlap et al., 2025; Sorman and Stock, 2024); (ii) marginalized populations may possess less political or social capital to contest large-scale land acquisitions (Dunlap et al., 2025); and (iii) renting or acquiring large contiguous land parcels is often easier in regions where economic activity and land prices are low.”, Lines 487-493											
15	<table><tr><th>Main criteria</th><th>Score (1-4)</th></tr><tr><td>Originality (novelty)</td><td>1</td></tr><tr><td>Scientific quality (rigour)</td><td>purpose 1; methods 1; discussion 1</td></tr><tr><td>Significance (impact)</td><td>3 Specific to Portugal. “Am I not convinced that the selected variables for classification are generally available?”</td></tr><tr><td>Presentation quality</td><td>1</td></tr></table> Excellent (1), Good (2), Fair (3), Poor (4)	Main criteria	Score (1-4)	Originality (novelty)	1	Scientific quality (rigour)	purpose 1; methods 1; discussion 1	Significance (impact)	3 Specific to Portugal. “Am I not convinced that the selected variables for classification are generally available?”	Presentation quality	1	Many thanks for this positive evaluation. We hope that by addressing the concerns present above we improve the general quality of this manuscript. We have also highlighted better the significance of this study for wider research and sustainability agendas, by better articulating how this work can be used for more just energy planning. “Am I not convinced that the selected variables for classification are generally available?” On distributive justice, a spatial lens reveals how more marginalized rural landscapes disproportionately bear larger and potentially more impactful projects. Such imbalances in ELS have the potential to foster a perception of geographic and energy injustice that can fuel	We hope that by addressing the concerns present above we improve the general quality of this manuscript. We have also highlighted better the significance of this study for wider research and sustainability agendas, by better articulating how this work can be used for more just energy planning. On distributive justice, a spatial lens reveals how more marginalized rural landscapes disproportionately bear larger and potentially more impactful projects. Such imbalances in ELS have the potential to foster a perception of geographic and energy injustice that can fuel
Main criteria	Score (1-4)												
Originality (novelty)	1												
Scientific quality (rigour)	purpose 1; methods 1; discussion 1												
Significance (impact)	3 Specific to Portugal. “Am I not convinced that the selected variables for classification are generally available?”												
Presentation quality	1												

	local resistance and erode trust in the energy transition (Kebblinski, 2026; Krüger, 2022; Mamonova and Franquesa, 2020; Sovacool et al., 2025). On procedural justice, our ELS approach highlights that, while projects document distinct levels of transparency and participation, most utility-scale ELS include very low levels of procedural engagement. In a context of accelerated permitting processes, there is a need for clear mandates for transparency, early and meaningful engagement, and demonstrable community influence over project design and decision-making (Boudet et al., 2025; ICLEA, 2025) (Boudet et al., 2025; Loomis et al., 2022). On recognitional justice, a land-system approach demands a place-based analysis to highlight how projects might adapt to local conditions, including levels of socio-ecological marginalization, through socio-ecological measures and co-location with other land uses. Nevertheless, the extent to which project recognizes local identities, knowledge, vulnerabilities, attachment to place, or culturally significant land relations in project design and decision-making remains unclear. Despite observed instances of more context-specific planning, rising social opposition raises critical questions: to what standards are we upholding RE projects, and through which energy models can those standards be met? Incentives, such as feed-in tariffs or low-interest loans, can be designed to mobilize a wider network of actors as agents in the energy transition. Such incentives could support innovative production models (e.g., battery storage and agrivoltaics providing additional income sources for farmers (Ali Khan Niazi and Victoria, 2023)), self-consumption, and energy communities. Utility scales projects could move away from financial compensation schemes towards financial participation.”, Lines 525-546 And highlight the transferability of our approach given available data: “Given sufficient project data, this approach can be adapted to other regions and customized, through targeted variable selection, to address specific research or planning needs, such as supporting advances in energy-planning models that incorporate social elements (Codemo et al., 2023, 2024; Krumm et al., 2022).”, Lines 570-572
--	---