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Review

A "spatially just" transition? A critical review of regional equity in decarbonisation pathways

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ABSTRACT

Spatial justice is a theoretical framework that is increasingly used to examine questions of equity in the low carbon transition (LCT) from a geographical perspective. We conducted a semi-systematic review to define a 'spatially just' low carbon transition, considering how spatial dimensions are explicitly or implicitly presented in assessments of the LCT, and the policy and governance approaches that could embed spatial justice. A sample of 75 academic articles was thematically coded. Spatial justice involves the fair distribution of *both* benefits and burdens associated with LCTs, and this often creates problems of equity given the geographic gap between regions that 'win and lose'. The studies point to a research gap in exploring fairness implications that go beyond the employment impacts of transition. Acceptance of the LCT is shown to be contingent on perceptions of justice, particularly whether the most responsible and capable actors are taking action. There is similar concern that the LCT may not address, or may *reproduce*, existing patterns of injustice. This is particularly the case in terms of spatially inequitable land uses and where historic planning policy has had lasting socioeconomic impacts. Policy challenges to making LCTs more spatially just included administrative fragmentation across spatial scales and the lack of coordination in net zero policy. We identify that future transition policymaking could benefit from using spatially targeted interventions, and in adopting a whole systems approach. In this recognition of the multiple economic vulnerabilities of different regions, LCT policymaking can become both more effective and, critically, more just.

1. Introduction

Over 100 countries have set, or are planning to set, net zero greenhouse gas (GHG) emissions targets [1]. Achieving this pace and scale of decarbonisation demands significant restructuring of national economies and societies [2]. Decarbonisation is often characterised as a uniform good, but increasing attention is being paid to the possible burdens associated with the low carbon transition (LCT) and how this might disproportionately affect already-vulnerable social groups [3,4] and create newly vulnerable groups.

The LCT has potential to generate both benefits and burdens, and there is a strong 'winners and losers' narrative in the literature [5–11]. Previously, LCT studies have been largely "aspatial" [12–15], though there is increasingly a so-called "spatial turn" [16] in assessments of LCTs. There is a key research gap in comprehensively exploring the spatial distribution of opportunity and opportunity costs associated with transition, and how these could intersect with existing geographical patterns of socioeconomic inequality. Spatial justice theory therefore provides additional value to the conventional "CEE framework" of climate, energy and environmental justice [17], in applying an explicitly spatial lens to the geographically variable impacts of the LCT.

We adopt a semi-systematic review methodology appropriate to integrating the diverse and interdisciplinary body of literature in this area, following Balzani and Hanlon [18].

The aim of this review is to explore what could be considered a "spatially just" LCT. The three core research questions were developed through a scoping study of the literature, identifying the main descriptive (question 1) and evaluative (questions 2 and 3) research gaps in discussions of spatial justice.

Research questions towards this aim include:

1. What spatial scales are considered in analyses of LCTs?

Abbreviations: CBA, community benefit agreement; CEE, climate, energy, environmental; CBDR, Common But Differentiated Responsibility; EV, electric vehicle; LCT, low carbon transition; MLP, multi-level perspective; NIMBY, not in my back yard; QDAS, qualitative data analysis software.

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2. How are spatial justice issues explicitly or implicitly presented in assessments of LCTs?
3. What policy and governance approaches could embed spatial justice in the LCT?

Section 2 provides an overview of spatial justice theory, and Section 3 outlines the methodology of the semi-systematic review. Section 4 presents the results and discussion, organised by the key themes drawn from the analysis of the literature, and responding to the above stated research questions. Section 5 outlines the conclusions of the analysis and directions for future research. As a review paper, rather than providing a comprehensive evaluation of several justice concepts, the following aims to assess the specifically spatial implications of justice in the LCT.

2. Context: spatial justice theory

Spatial justice is an infrequently used theoretical framework that can be employed to examine questions of equity and fairness in the LCT from an explicitly geographical perspective. As noted by Sovacool et al. [19], the spatial and scalar implications of just transitions are important areas for further research. Spatial justice theory has a long and interdisciplinary prehistory, which merits further exploration in the context of decarbonisation and the primacy of the just transition debate.

Spatial justice is conceptually rooted in the field of political geography, building on the work of key social justice theorists such as John Rawls, as well as critical geographers including David Harvey and Doreen Massey [20]. Rawlsian justice advocates for the fair distribution of social primary goods, and this has clear application to issues of spatial distribution [21–23]. Therefore, the conceptual leap from social to spatial justice is not a large one. Harvey's 1973 work on urban social justice advanced the concept of "territorial social justice", and responded to an earlier 1968 study documenting the spatial variation in social service provision [24,25]. But it was work by Pirie in 1983 that provided conceptual clarity and the first direct use of the term "spatial justice" [25].

Bridge cites the "spatial turn" of energy research since the 2000s [16], and there has been corresponding growth in spatial environmental justice studies since this date. Edward Soja's "Seeking Spatial Justice" [26] documents a successful grassroots legal challenge to the public transport authority in Los Angeles, resulting in the reform of the mass transit system to favour the needs of the poorest residents of the city. This represented a triumph of spatial planning for social good, and has clear applications to environmental justice in considering how changes under the LCT should also improve social wellbeing. Soja therefore offers a linkage between spatial studies and contemporary debate on environmental justice. This issue is foregrounded in Bouzarovski and Simcock [13], which provides a model point of departure for this review.

The lack of prior critical attention to this theoretical framework is perhaps attributable to weak consensus on its epistemological value. Criticisms of the term focus on the following four areas: a) its uncertain definition; b) the "causality" of injustice; c) its perception as environmental determinism; d) disciplinary biases. Spatial justice ostensibly critiques the role of space or geography in driving or determining socioeconomic inequalities. However, there is considerable critique, particularly from the body of political geographers, that spatial justice is essentially "social justice in space" (p. 471, [25]). Indeed, whilst Pirie originated or at least popularised the term spatial justice, they argue that spatial dimensions are simply a descriptive characteristic of existing social inequalities, rather than a causal factor in their creation. Additionally, as Harvey noted in the early history of the term, in any case of socio-spatial "injustice" the choice of scale will determine the relative distributional "justness" [26,27]. There is similar criticism that an overt focus on the spatial dimensions of justice detracts from the discussion of the "vertical" power structures and dynamics which underlie cases of inequality [28]. Soja offers a resolution to the tension between space as social construct or product of class relations, and space as arbitrary descriptive structure, by proposing a "socio-spatial dialectic" [28].

A further critique is in the characterisation of spatial justice as a species of "environmental determinism", wherein geography controls an individual's life chances and quality [28]. As Soja (p. 4, [26]) highlights:

> this persistent asymmetry between social and spatial explanation reflects in part a long-standing disciplinary precaution amongst geographers against giving too much causal power to the spatiality of social life for fear of falling into the simplistic environmental determinism that plagued geographical thinking in the past.

"Luck egalitarianism" suggests that when people are affected by circumstances beyond their control (e.g. being born in a certain region) this is an injustice. Though Rawls has been criticised for holding this position, he writes that "it is [not] unjust that persons are born into society at some particular position […] these are natural facts […] what is just and unjust is the way that institutions deal with these facts" (p. 24 in [23,22]). In this way spatial justice theory responds to accusations of environmental determinism in suggesting that it is socio-spatial institutions and power structures which co-constitute a geography of opportunity alongside geographical characteristics. Therefore space and the social institutions which constitute it should be a subject of further scrutiny by justice studies.

Some argue that there is no "additionality" in the term in comparison to existing justice concepts, for instance those in the Climate, Energy and Environmental (CEE) justice framework [17]. Further work justifying the critical value of this separate but complementary justice concept would therefore be useful, as in the approach taken by Jenkins [29] outlining the additional remit of energy as well as climate justice. Whilst theoretical debate on the value of "spatial justice" should inspire critical caution around use of the term, it is nevertheless a "useful" concept in the context of the spatially differential quality of environmental justice issues. It is perhaps helpful to adopt Soja's definition of spatial justice as representing "a particular emphasis and interpretive perspective' rather than a 'substitute or alternative to other forms of justice" (p. 13, [26]). Other discursive work suggests that space should be considered as "a social product rather than a context for society" [25], partially overcoming some of the above stated critique, in recognising the mutualistic relation between space and society.

In addition to the CEE framework, justice is frequently framed in three core terms: distribution, procedure, and recognition. The concepts have clear spatial implications and are therefore useful framings through which to discuss spatial justice. However, these spatial dimensions are not often documented in the literature, resulting in a research gap which we aim to address here. In the context of the LCT, distributional justice refers to whether the benefits and burdens of transition are allocated evenly across society [30], and critically, across space. Procedural justice is fairness in the opportunity to be consulted and included in decision-making processes, particularly around new energy developments in the case of the LCT [31]. Procedural justice may be spatially variable where there is less engagement with certain communities or regions, or democratic infrastructures are less in place within certain regions to enable this participation in LCT decision-making. Recognition justice is the acknowledgement of divergent identities, cultural histories, and power dynamics, and how these may interact with proposed changes under the LCT. Space is particularly important to recognition justice in terms of recognising specific place identities and how these may shape the acceptability of transition measures.

Equity principles can be considered as a means of achieving just outcomes, and in this review we address the core issues of responsibility and capability [32,33]. Responsibility refers to fair burden-sharing by those regions which currently receive most benefit from a given activity or have most contributed to high emissions historically, whilst capability may be defined as the ability of regions to respond to the need to decarbonise or the possible burdens and costs imposed by the LCT.

In this project we therefore take forward the approach outlined by Soja and others in using "spatial justice" as a critical analytical perspective through which to assess the socio-spatial changes emerging and likely to emerge as part of the LCT. However, spatial justice can be broadly defined in this context as "the fair geographic distribution of benefits and burdens associated with, and arising from, the low carbon transition". Bouzarovski and Simcock [13] provide an examination of spatial justice issues in the context of the energy transition, interrogating the household impacts of energy poverty, and identifying "that there are clear geographic patternings associated with energy poverty, as well as the geographically embedded and contingent nature of its underlying causes". We follow the approach of Bouzarovski and Simcock [13] in applying spatial justice to the LCT but depart in considering the whole system impacts of transition; that is, considering cross-sectoral and economy-wide impacts beyond energy supply and demand.

3. Methods and research design

We conducted a semi-systematic (or integrative) literature review, defined as "a form of research that reviews, critiques, and synthesizes literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated" (p. 356, [34]). Semi-systematic differ from "full" systematic reviews in their emphasis on generating new, mainly qualitative, insights from interdisciplinary literature rather than a full capture and quantitative analysis of records. Although systematic reviews guarantee an objectivity, reproducibility, transparency and rigour [35,36] that cannot be provided by narrative review methods, a full systematic review was not considered appropriate for this research question. Several factors qualify the use of the integrative review approach in this study, namely:

a. the research area is highly exploratory [36] and there is limited available literature in this space;
b. the review takes a deliberately interdisciplinary approach, recognising the value of contributions from such diverse fields as geography, regional studies, ecological economics, and the humanities (as evident from a pilot literature search). Integrative reviews are seen as particularly useful where the available literature is interdisciplinary [18,34,37];
c. the variability of methods in the relevant literature limits comparability and makes it difficult to perform meaningful quantitative meta-analysis [38].

However, we have applied as far as possible the principles of a systematic review approach inasmuch as they improve the rigour of the research [35]. A "continuum" of more or less systematic review approaches is frequently cited [35], where this review aims to lean towards the systematic end of this continuum. The search was conducted with reference to the systematic review guidelines of Liberati et al. [39], and with the integrative review guidelines of Torraco [34,37].

We developed the research questions framing the analysis on the basis of a pilot search of the literature, which also helped to identify what the key research gaps are. It also provided opportunity to test the search criteria and strategy, and helped identify relevant terminology in the research area to inform the search terms [38].

The literature search was initially conducted in February 2021, with a follow-up search in July 2021 to capture any later published articles. It is possible that relevant material has been published in the interim period between the date of the review and the publication of this analysis. The search used the Web of Science and Scopus databases, as well as citation searching of key papers. The process is described in Fig. 1.

On the basis of the pilot search, the key terms of the research questions and their synonyms were used. We identified 78 potential variants of the search criteria (i.e. synonyms), therefore we refined this selection through Boolean, truncation and wildcard search techniques (see Table 1).

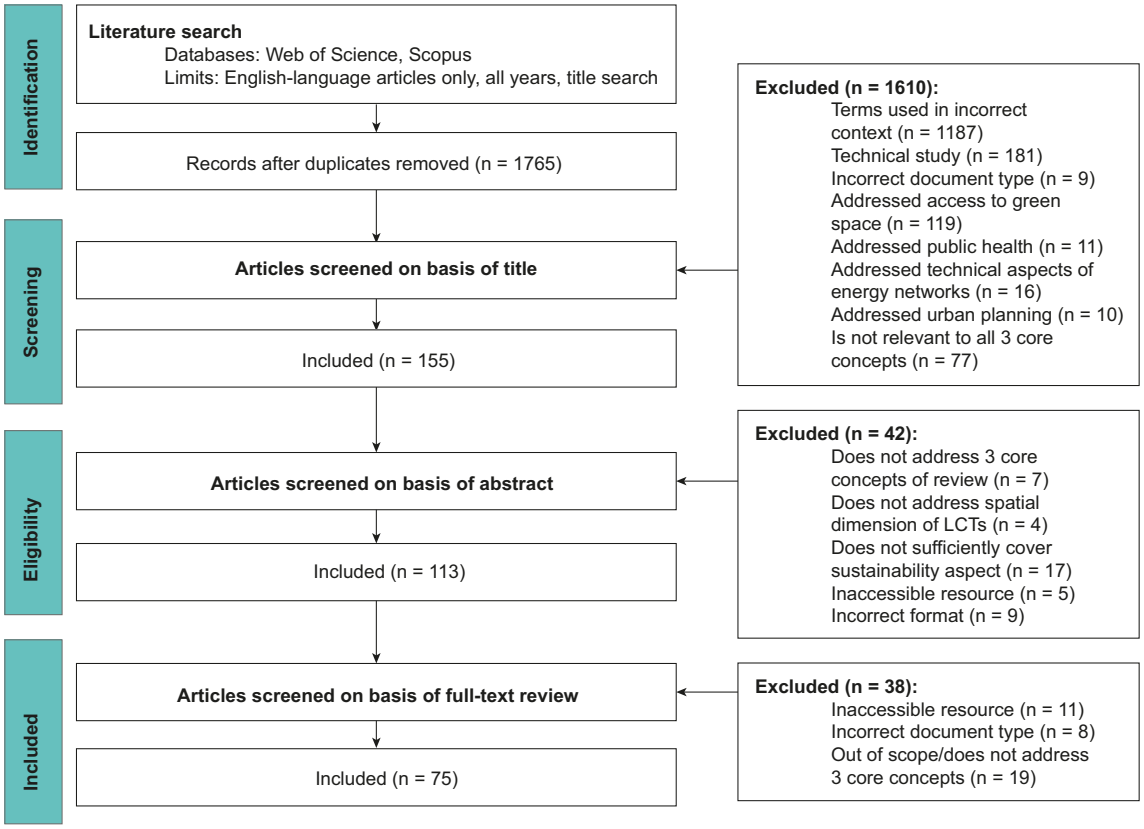

Fig. 1. Flow chart of review process (PRISMA format).

Table 1
Summary of the search strings used, and the aspect of the research question they address.

Dimension	Element of search string
Spatial	TITLE: (spatio* OR spatial* OR geograph* OR "place-based" OR region* OR space OR scalar OR provincial OR polycentr* OR devol* OR decentral*)
Justice	AND TITLE: (justice OR just* OR "just transition" OR fair OR equal* OR *nequal* OR equit* OR inequit* OR injustice OR inclusive OR "climate justice" OR "energy justice" OR "environmental justice" OR disparit* OR democra* OR distribution* OR "social equity")
Low carbon transitions	AND TITLE: ("low carbon transition" OR "low carbon transitions" OR "low carbon economy" OR "low carbon" OR "net zero" OR "net-zero" OR "zero carbon" OR "zero-carbon" OR "carbon neutral" OR "sustainable development" OR "sustainable transition" OR sustainab* OR "climate change mitigation" OR "green recovery" OR decarbon* OR "energy system transition*" OR green* OR mitigat* OR "low-carbon transition" OR energy OR "energy system")

The final sample included 75 records and the sample size was deemed sufficient given the specificity of the research area; similarly, the inclusion criteria meant that each study must explicitly address each of the 3 core dimensions of interest (spatial dimensions, justice, and the LCT). Meta-analysis of the final full-text sample (n = 75) was undertaken. A number of descriptive criteria were identified to help characterise the literature including case study location, the justice framework utilised, and methodologies employed.

We took an inductive and exploratory approach to analysis of the final literature sample and performed thematic analysis using qualitative data analysis software (QDAS; NVivo Plus v.12.6). An inductive approach was considered appropriate due to the exploratory nature of the research question [40]. Thematic analysis was identified as more appropriate than content analysis, since the latter refers to a more quantitative method involving, for example, word count frequencies [41]. We analysed the entire sample using an iterative thematic coding approach until we considered we had reached "theoretical saturation" (where no new insights were being generated, and there was a sense of consensus amongst the themes identified).

3.1. Methodological limitations

Whilst every attempt has been made to ensure the review's rigour, transparency and validity, we acknowledge that there could be room for improvement and note the importance of reflexive critique in research design.

The review technique could have been more systematic (indeed classed as a full systematic review), had the exclusion criteria been more defined, and the records included in the final sample been subject to review by several authors rather than only the lead researcher. The exclusion criteria adopted are found in Fig. 1, and included both functional and thematic criteria ranging from "includes key terms but in an incorrect context" to "not encompassing the three core concepts of the review" (e.g. spatial factors, justice issues, sustainability). Similarly, many important resources may have been omitted due to the linguistic bias in only selecting articles written in English. The final sample may also simply reflect disparities in where climate and LCT research is funded, rather than where spatial justice issues are most problematic and in evidence.

The final sample is necessarily a product of the search string, and perhaps notably missed many useful articles from the field of regional studies. A key methodological improvement could involve broadening the search criteria to better encompass disciplinary terminologies to ensure breadth of coverage in the final sample. However, the search string was deemed sufficient for the purposes of this analysis and in achieving a manageable sample size.

Whilst details of the search and screening process and the records in the final sample have been clearly documented to improve transparency, the findings of the review would not be clearly reproducible given the qualitative and "thematic" nature of the analysis. That is, other researchers might identify other issues as more important, and there is a subjective dimension to the coding process. Similarly, the review was undertaken at a specific point in time, therefore the results could look different if the searches were run at a later period. This suggests the results may not be generalizable across time.

However, in adopting an integrative review approach, we hope to overcome the issue of disciplinary bias [42], and in employing full systematic review techniques we aim to achieve a level of research rigour as far as practicable [35].

The subsequent review is structured conceptually, drawing on the high-level categories that emerged from the thematic analysis. The review begins with a general characterisation of the literature based on the meta-analysis, before considering the spatial scales of interest in LCT studies in response to research question 1. The subsequent discussion addresses research question 2 and considers distributional, procedural and recognition justice in terms of space, before examining how these issues feed into the acceptability of transitions in different regions, with reference to the equity concepts of capability and responsibility. We then consider issues such as the role of spatial planning and the legacy of previous transitions, before suggesting challenges and solutions for spatially just policy and governance approaches aligning with research question 3.

4. Results and discussion

The full-text screening resulted in a sample of 75 final studies, covering a range of disciplines with 24% in the field of geography, and with 85% published in the last 10 years (see Fig. 2).[1] The small number of records found for the year 2021 may reflect that the search was conducted early in the year. During the screening process many studies had been excluded on the basis of an unclear conceptualisation of "sustainability", and failing to consider issues such as climate change mitigation, decarbonisation or emissions (the aspect of explicit interest to this study in considering low carbon transitions in their broadest sense).

Similarly, whilst many papers provided descriptive studies of linkages between environmental pollution and spatial variables (for

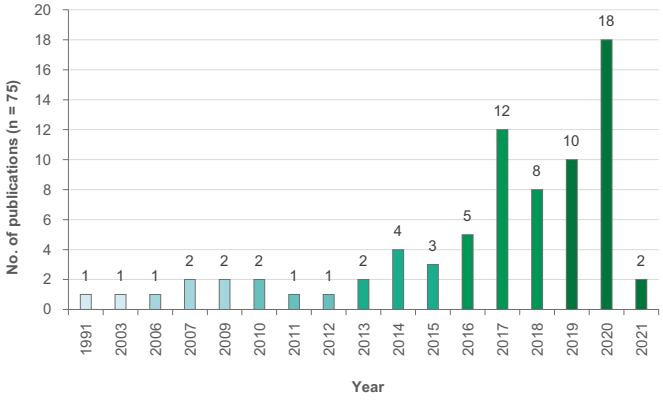

Fig. 2. Bar chart outlining the number of records per year from the full-text sample (run in February 2021). No publication date exclusion criteria were applied in the search.

[1] See Appendix A for further discussion of the meta-analysis results, the codebook and for the full list of studies included in the sample.

instance correlations with Gross Domestic Product, GDP), many papers did not explicitly include any acknowledgement of the justice issues which may have driven such distributional issues. This also formed another exclusion criterion. This reinforces the importance of drawing a distinction between in*justice* and in*equality*; that is, spatial inequalities do not mean de facto spatial injustices. The terms are generally used interchangeably in the literature however [43].

Healy et al. [44] identify that "injustice" is frequently used as an umbrella term for any environmental harm, which elides the different scales of harm and relative vulnerabilities for communities in the Global South as opposed to the North. Inequality can be understood as the descriptive difference in a socioeconomic variable between regions, whereas injustice suggests a dimension of unfairness in the socioeconomic conditions certain regions face relative to others and in how one area is treated over another.

In addition to the "vertical" question of spatial scale considered in the studies, the final sample also included a broad range of case study locations. Over three quarters of the papers featured a case study in a developed country, indicating a research gap in the consideration of spatial justice issues in the developing world, perhaps as a result of the unequal distribution of research funding between these regions. For instance, a recent study found that only 3.8% of global climate change research funding is spent on research in African countries [45]. The majority of case studies were located in Europe (34%), the UK (23%), and North America (19%). This may be attributable to more clearly devolved subnational powers and administrative structures in these regions, making an intranational spatial approach of greater interest to exploring the LCT given the powers available to influence it. There may however be a geographical bias as a result of the linguistic bias (due to the exclusion criterion of only "English language" articles due to the capacities of the research team).

Methodologically, the most common approach in the study sample was use of a "conceptual framework" (n = 15), whilst 7 studies provided indicator framework assessments. Many question the usefulness of theoretical frameworks given the climate emergency and continually rising emissions, debating how they may be operationalised or put into practice [29,46]. This may in part explain the rising phenomenon of the "indicator framework" methodology, which attempts to quantify and track progress and justice in an aspect of the LCT.

The studies had three main areas of critique towards previous research, pointing to ongoing research gaps, namely: a) aspatiality or a national scale bias; b) the use of income-based metrics to assess relative injustice; c) the predominance of the "green jobs" debate in just transition studies.

The studies critiqued the aspatiality of previous research [12–15]. A frequent argument was that a lack of geographical perspectives disguises the spatial phenomena that are environmental injustices. Other critique of the spatial approach of LCT analyses focussed on the disproportionate bias towards one scale rather than adopting a multi-scalar approach [2,4]. The national scale was frequently cited as the focus for many LCT studies when space was discussed [12,47–49], with many suggesting this was due to the concentration of (policy) power at higher order scales [50,51]. A multi-scalar approach was viewed as important in assessing the variable subnational impact of national policies [52].

A further critique lay in the predominance of income-based analyses in the existing literature, for instance the use of "expenditure metrics" such as the energy expenditure-to-income ratio used to determine relative energy poverty rates [48,53–55]. The choice of indicator or metric determines the patterns of injustice that are likely to be found. Whilst expenditure and income are important spatial variables, they are not the only or necessarily the most important explanatory factors in assessing injustice [54–57]. For instance, Reames [56] show that patterns of racial segregation significantly influence exposure to fuel poverty.

In other critique of the prevailing focus of existing literature, Balta-Ozkan et al. [12] drew attention to the primacy of the "green jobs" narrative to the exclusion of other areas of impact associated with the low carbon transition. Sareen and Haarstad [58] critique the disciplinary and normative split between the supply-focussed sociotechnical transitions studies and the demand-side basis of justice analyses. Emerging scholarship is indeed addressing the supply-demand dichotomy in considering embodied injustices along both fossil fuel and renewable energy supply chains [44].

4.1. What spatial scales are considered in analyses of LCTs?

Spatial scale is a term which, like spatial justice, has lacked definition but has a long history of academic debate. Whilst extensive discussion of "ontologies" of spatial scale are beyond the scope of this review paper, we summarise a few key perspectives as follows.

Several authors engage with what has become known as the "politics of scale" [59,60], and with whether scale should be considered in a vertical, hierarchical, or nested model, or conceptualised as a "flat ontology" [59,61]. The multi-level perspective (MLP) has been viewed as typical of the "nested hierarchy" model, and is a means of characterising sociotechnical transitions of significance to the LCT debate. MLP theory posits that transitions occur due to interactions at several levels including: niches, socio-technical regimes and the socio-technical landscape [49,62]. However, flat (non-vertical) conceptualisations of scale suggest more agency for actors to exact change across scales and have been forwarded as a more accurate scalar model for LCT studies. Others suggest that scale is a socially constructed entity [60,63] and attention is drawn to its "relational' nature" thus making most definitions by nature reductive.

In response to the first research question, the studies in the final sample considered a wide range of spatial scales, from the local, community, neighbourhood, or city-scale, to the world "region". It is critical to note that any definition of "regional" is conditional, as the term may describe any spatial subdivision of a larger whole; as noted by Sovacool et al. [64], "scalar categories are relational". This corresponds with the above stated critique of any stable and bounded definition of "spatial scale". Similarly, administrative boundaries are not always the most relevant definition of space, given processes which occur outside the bureaucratic oversight of regional authorities and given transboundary activities; that is, administrative designations do not always match the lived reality of communities [65]. However, the administrative definition of a region may be useful insofar as it indicates where devolved policy powers may lie [66].

Injustices are also dependent on the assumed spatial scale of the analysis, since there are inequalities both within and between regions. As a partial corrective to this, and building on the work of Amartya Sen, Fisher [67] argues that "justice must be comparative", that is, the relative injustices between regions in the UK for instance are of a different order to injustices between developing and developed nations. There are also issues of whether injustice can or should be monitored through objective or subjective metrics [48]. Lawhon and Patel [68] note that "the choice of scale influences whether injustices are found". For instance, whilst London is one of the most affluent regions in the UK, the London boroughs are not ubiquitously wealthy and many have the worst poverty rates in the UK (depending on the assumed metric of "poverty"). Therefore reductive binaries such as the "North-South divide" in the UK, or even the Global North and South, are not always appropriate as conceptual shorthand for injustice. Similarly, Sauter et al. [69] observe that intranational inequalities in CO_2 production can be greater than international inequalities, as driven by sectoral inequalities in their global study.

Available data at different spatial scales, as well as the use of data and metrics may determine the perception of relative spatial injustices. For instance, the aggregation of high resolution data can disguise important trends occurring at the subnational scale, often known as the "modifiable areal unit problem" [13,70,71]. Similarly, the "social cost of carbon" (a measure of pricing marginal CO_2 emissions to reflect the

social implications of future climate impacts) is found to double when estimated at the intranational rather than international scale. This is due to variations in income distribution within countries, highlighting regional vulnerabilities and therefore analytical sensitivities to assumed spatial scale [52,72].

In this way, the assessed studies considered a variety of spatial scales. However, there remains scope to correct the previous "aspatiality" of LCT studies, as noted by work proposing whole systems approaches and for greater consideration of the spatial implications of energy justice [19,31]. There is similarly need to address the predominance of focus on the national scale, and to more critically consider the choice of "injustice metrics".

4.2. How are spatial justice issues explicitly or implicitly presented in assessments of LCTs?

4.2.1. Distributional justice across space

Spatial justice in the LCT can be defined as the fair geographic distribution of benefits and burdens associated with, and arising from, the low carbon transition. Distributional justice refers to the "physically unequal allocation of environmental benefits and ills" [30] and is therefore an inherent feature of spatial justice theory. Successive studies addressing spatial justice similarly employ a rhetoric of benefits and burdens. For instance, Jenkins et al. [73] highlights the need to distribute both fairly in order to ensure a just transition. There is often disproportionate focus on the burdens of transition [74], which has somewhat been reshaped by debate over "green recovery". "Green recovery" is a policy discourse common in the wake of the COVID-19 pandemic, hoping to stimulate economic growth whilst also achieving reductions in emissions. In seeking policy support, many parties have framed transitions activities in terms of economic co-benefits and exploited potential to channel countercyclical investment towards decarbonisation [75]. It is in essence a multiple benefits approach to economic development, comparable to previous attempts to implement a "Green New Deal" – a package of public policies that address climate change whilst improving wellbeing.

A spatial justice perspective builds on the just transitions literature in identifying that the benefits and burdens of transition may not be distributed equally across space – for instance, new opportunities may not arise in the same places where there have been opportunity costs [2]. There is the additional need to ensure that any negative consequences of transition do not exaggerate existing patterns of deprivation, as there was a key concern in the literature that the LCT could reproduce existing inequalities.

Debate in the assessed studies around the spatial distribution of benefits and burdens associated with LCT shaped a narrative of regional "winners and losers" [5–11]. Though many studies are unclear as to the specific actors and/or regions that fall into either category, "winners" ranged from regions which have a cost-optimal allocation of the remaining burnable coal reserves [6] to children who benefit from the phaseout of nuclear energy in Germany due to lower risks associated with waste disposal [10]. "Losers" included Nordic oil and gas regions [9] and other areas with high concentrations of heavy industry and/or fossil fuel production, or else regions with plentiful clean energy resources but with local opposition to exploiting such opportunities [9]. Roberts [7] goes so far as to suggest that the winners and losers of environmental change and social injustice are comparable groups. A paper titled "Regional winners and losers in future UK energy system transitions" [70] identifies that the regions characterised as "winners and losers" will be dependent on the precise socio-technical scenarios and policies implemented at the national scale, as determining where investments (particularly in the energy system) are directed. From a justice perspective, "winners and losers" narratives take issue with the very creation of "losers" or the further penalisation of "losers" from the current socioeconomic status quo. From a spatial perspective, this narrative addresses the idea that certain regions are more susceptible to further "losses" from transition policies.

A similar trend was in the discussion of "left behind" places which returned 7 direct references in a word query of the sample, a term commonly found in the regional development literature and generally describing areas facing multiple deprivation. Demeterova et al. [76] note Europe's "fiscally weaker" and "lagging" regions, despite efforts via the European Territorial Cooperation (ETC) initiative (or Interreg) to improve cohesion between EU states across borders and scales. They also highlight that such regions are likely to be more vulnerable to climate impacts, therefore reinforcing "existing spatial inequalities". They argue that there is a need for "regionally anchored definitions of success", that is, regional development pathways specific to the context rather than a prescribed national definition of sustainable development. This accords with arguments for recognition justice as is later discussed. Others cite the just transitions commonplace of "leaving no one behind" [14], a truism challenged by several authors, who critique the assumption that everyone is starting from the same place. It could perhaps be argued that there are pre-existing socioeconomic "losers" who risk becoming more vulnerable as a result of transition policies.

Lihtmaa et al. [77] cite the post-industrial regions of former socialist countries such as Estonia, where although access to subsidies was ostensibly even, the take-up of subsidies reflected pre-existing regional inequalities. In essence, there is a suggestion that certain communities and regions already face post-industrial deprivation and are not therefore starting from a position of equality; there is then the risk of "double deprivation" from transition policies. Comparably, the UK's "levelling up" agenda (announced during a 2019 election campaign) ostensibly aims to even out current regional inequalities across the country [78]. This particularly concerns relative differences in productivity levels and standards of living. The rhetoric acknowledges the uneven starting places of regions, but suggests there is a normative or target "end state" that all regions can and should reach.

Discussion of benefits arising from the LCT primarily centred around employment opportunities, building on the just transitions literature focus on fossil fuel jobs. Further to the discussion of where new jobs will be created was a deeper debate around how the transition will affect opportunity structures for different regions, particularly a concern over the spatial equality of opportunity [7,13,14,79]. Finio et al. [80] similarly refer to the "geography of opportunity". There is an assumption in much of the green jobs literature that such opportunities will be created in the areas where they are most needed, and that skills will be transferable between industries old and new [9,10,81]. There was also concern over the relative quality of the new transition jobs, and whether they provide an adequate or desirable substitute [82]. There is an element of environmental determinism in the frequent discussion of how the location an individual chooses to live in, or is born into, informs their life chances; as Bouzarovski and Simcock [13] note "where a person lives seems at least as significant as the socio-economic group that they are part of", and Robinson et al.'s [54] conclusion that "where you live matters in addition to who you are".

More than the specific new burdens generated by the LCT, there was therefore a concern with how they would interact with existing socio-spatial inequalities and injustice. Several authors drew attention to how some regions are more vulnerable, and are intrinsically more sensitive to issues such as electricity price rises [64,83,84]. For instance, Sovacool et al. [64] identify that the UK smart meter rollout could drive rising household energy costs when users cannot respond to energy data by changing tariffs, reinforcing vulnerability in households facing fuel poverty. At the national scale, regional socioeconomic inequalities are driven by rising energy costs where energy bills are used as a means to fund the development of low carbon infrastructures [10]. Sovacool et al. [10] cite the potential for cost pass through to consumers in LCT activities as diverse as French nuclear decommissioning and Norwegian electric vehicle (EV) subsidies. This has led to calls to fund low carbon energy systems via a general taxation approach [85]. Carley et al. [84] adopt a "vulnerability scoping" method applied to the US renewables

rollout to assess these types of distributional impact.

Geographical differences may lead some regions to benefit more from the resulting low carbon infrastructure than others. For instance, where network structure affects the accessibility and price of different energy carriers, particularly affecting rural and otherwise peripheral regions that are dependent on certain fuel types and who may be less able to access subsidies [3]. Bouzarovski et al. [83] also note this vulnerability due to spatial dependencies on certain fuel types, noting the case of "post-communist" states where rises in electricity tariffs drive use of "affordable fuels such as coal and firewood". This vulnerability is compounded by pre-existing socioeconomic disparities such as inefficient housing stock. Policy was viewed as a key means of controlling the spatial distribution of this type of burden, particularly in issuing financial and technical compensation and assistance [86].

In the discussion of burden distribution, a recurring concern was how industrial regions specifically may be adversely and disproportionately impacted by transition policies. As either regions which have suffered from the economic fallout of deindustrialisation in many developed states, or else regions where polluting industrial activity is still concentrated, such regions can be seen as more vulnerable to the policy cost burdens of industrial decarbonisation. For instance in Vandyck and Van Regemorter's [87] case study of the impact of a Belgian energy tax, they find that "due to the sector composition, GDP in the region that hosts more energy intensive industries […] decreases". Another source of vulnerability stems from the importance of the industry to regional employment – similar to the Company Town model in the US, where industry constitutes the main employer for the region. Regions dependent on single industries or companies for employment are disproportionately vulnerable to climate policy and transition (as well as other forms of economic shock), given the negative economic spill-over effects into the local economy if industry is forced to become less productive [15,88]. Rising electricity prices also have an indirect spatial impact here when they affect the competitiveness of industrial regions and in turn their employment base [84], carrying the risk of industrial offshoring.

The studies also explored a number of other typologies of "space", for instance the difference in injustice between rural and urban land uses [7,12,89–92]. Rurality was considered "under-explored" and a predictor of spatial injustice [89]. Rural communities were seen as both more vulnerable and less able to benefit from some of the opportunities arising in the course of the LCT. For instance, rural regions are typically more susceptible to energy poverty due to limited access to energy services and a dependence on oil for heating for example [55]. Similarly, rural areas are seen as less able to benefit from the transition to EVs and policy incentives to support this [93,94]. The systematic privileging of urban areas was suggested, in the argument that policy prioritises areas of concentrated and homogenous deprivation [54]. However, specific opportunities for rural areas in the LCT include the potential for decentralised energy generation technologies [12].

Several studies considered the geographic gap between benefits and burdens in the LCT as a public good problem, concerning the fair spatial distribution of environmental externalities but also opportunities [10]. This issue may manifest in more or less tangible forms, for instance in dispute over energy infrastructure siting, or else the distribution of policy costs for infrastructures which may serve one region better than another. This is particularly relevant when considering renewable energy infrastructure siting for instance, where questions have been raised over the viability of placing the infrastructure in an area that meets local resistance whilst ostensibly serving national decarbonisation needs [4,12]. This scalar mismatch in interests, where a new infrastructure is "locally unwanted" but nationally needed [89], is often articulated as "NIMBYism" (or "not in my backyard"). This relates to the scalar problem framing of climate change as a "global" issue, and therefore not a cause for local responsibility-taking [95].

The literature on the distributional justice issues of the LCT accord with current policy proposals (for instance around levelling up and green recovery) that reflect concern around socio-spatial inequalities. Yet there is a key research gap in considering the types of policy and governance tools which could bridge the disparity in where benefits and burdens are distributed to inform this policy agenda. Overall, the degree of interest in questions of distributional justice is well reflected by the number of records in the sample discussing it. This perhaps points to an imbalance in the literature in terms of the preoccupation with distribution over other dimensions of justice (for instance recognition and procedural justice).

4.2.2. Procedural justice within regional transitions

In the context of the LCT, procedural justice is the fair opportunity to be consulted on proposed developments and to engage in the planning process. Procedural justice may refer to both participating in processes of responding to environmental "bads", but also the fair opportunity to secure the provision of environmental "goods" (e.g. access to green space, ecosystem services, pro-environmental subsidies, renewable energy developments) [9,96,97]. Lihtmaa et al. [77] cite Meadows' "success to the successful systems trap" whereby communities or social groups with pre-existing social capital are better placed to benefit from the LCT, for instance in access to subsidies. This contributes to a vicious cycle working against social mobility, and perpetuating existing socioeconomic power structures. There are also disparities in the spatial distribution of other forms of capital. In the case of community energy cooperatives for example, there may be a lack of financial capacity to contribute, or else a lack of knowledge or skills to initiate the project [98,99]. So-called "human capital", the knowledge and skills individuals possess [101], is therefore a constraint to collective action, particularly in terms of transition activities which require technical expertise.

Conversely, environmental harms are more likely to occur in more deprived areas, given a lack of social capital and the potential for less resistance to the harms imposed. As Mueller and Brooks [89] note, "industries siting locally unwanted land uses know they face costly opposition, and therefore choose to target areas with lower social and financial capital, where local opposition has historically been less effective." Social capital is spatially varied, meaning different regions and communities have variable capacity to respond to the placement of burdens during the transition. Whilst such issues are applicable to environmental assessments in general, this highlights the importance of attending to spatial dimensions in assessing the relative justice of transition policies and measures.

Procedural injustice may occur when affected communities are not appropriately consulted on potential LCT developments. This may result when the definition of "those affected" is incorrectly drawn or in drawing spatial boundaries as a means to define a "community" [102]. Walker indeed argues that geography has a key role in the "inclusions and exclusions of environmental decision-making", influencing the ability of citizens to participate in decision-making meetings virtually, or even have time to attend such events [103]. In broad terms, citizens' assemblies are an increasingly popular governance tool which go some way to address such issues of procedural injustice. The assemblies are being used as fora by which citizens can participate in local and regional decision-making around climate mitigation and adaptation, amongst other social issues [104]. The assemblies aim to include a representative cross-section of civil society in creating regional LCT development pathways, therefore the recruitment process renders this a means of achieving recognition justice.

In this way, the design of procedural justice mechanisms has significant implications for achieving recognition justice, and there is a co-dependence between the two. That is, procedural justice involves *recognising* those who are affected by a given development and who have the power and authority to influence LCT decision-making [105], and recognition justice is enacted by fair *procedures*.

4.2.3. Recognition justice and place identity

Recognition justice "acknowledges the distinct identities and

histories of people in relation to the energy system and seeks to eliminate forms of socio-cultural domination" [92]. In transition studies recognition justice therefore becomes a means of accounting for cultural context and determining developments which are "locally appropriate". Failure to consider recognition justice can lead to localised resistance to proposed developments. As Devine-Wright [106] (in Sayan, [8]) suggest, "place-protective actions […] arise when the siting of […] energy technologies […] threaten place-based identities". This is evident in local objections to wind energy developments in rural areas [107], and conversely in local encouragement to fossil fuel developments in ex-mining regions [81].

Several studies identified that there was a need for caution in that existing "place identities" could present a barrier to transition policies, where certain regions are heavily characterised as sites of fossil fuel production; for instance, Evans and Phelan's [81] case study of resistance to transition in an Australian coal mining region. The "stigmatization" and "misrecognition" of place can drive undesirable development, meaning certain areas and land uses face consistent marginalisation [108]. Rudolph and Kierkegaard [109] notably discuss "territorial stigma" as both a result of and as driver of undesirable development.

"Place-protective" actions have the potential to delay renewable energy projects and other important transition policy measures. For instance, in a case study of a Canadian transboundary region a proposed cooperative system of governance received little support due to concerns over the loss of place-based identity [110]. There is similarly a need to consider historic identity and how this may shape the acceptability of different transition policy measures. In Japan, a risk-aversity to certain energy developments is observed given the definitive experience of Fukushima [95].

Recognition justice is particularly important in regions where communities experience a close cultural connection to their landscape, to the extent that place becomes non-dissociable from identity [82,111], and where radical environmental change risks creating a sense of "solastalgia" [89]. Recognition justice therefore draws attention to the need to consider non-monetary place attachments – that is, where a sensibility of place and local value is important in shaping what kind of transition is acceptable or even desirable.

Table 2 provides a summary and case studies of the spatial justice implications of each of the main justice dimensions, before the discussion moves onto the equity principles of acceptability, responsibility and capability.

4.2.4. *Acceptability, capability, responsibility*

The above discussion of the spatial implications of the LCT has drawn attention to the importance of visible distributional, procedural and recognition justice in rendering the transition "acceptable".

A key finding across the study sample was that the acceptability of the LCT will be dependent on justice, particularly in who receives benefits or burdens [113]. Acceptability is a litmus criterion for the viability of the LCT, with low acceptance resulting in public mistrust, or at worst, active protest [10,32,114]. As Yenneti et al. [82] note, "the lack of trust can make even 'environmentally good' renewable energy projects face resentment." This is particularly important at the intranational scale, where disparities in those receiving more benefits than burdens may be more immediately "visible". For example, there is a significant body of literature exploring the distributional and potentially regressive outcomes of energy taxes [87], with some proposing general taxation and other approaches as means to improve fairness [85,115].

Another key conclusion was that it was the *perception* of justice that counted, rather than any more substantive form of justice. This ties to the concept of perceived responsibility, which feeds into "discourses of delay" rhetoric around the need for others to take action first [116], and the leader/laggard or "prime mover" problem. This runs against the trend of indicator framework studies for instance, in suggesting that rather than justice being clearly quantifiable, the impression of relative

Table 2
Spatial aspects of core justice dimensions.

Dimension	Spatial justice implications	Case studies
Distribution	Benefits and burdens of the LCT could be unevenly distributed across space, intersecting with pre-existing, and creating new, inequalities	• Oil and gas producing regions facing ongoing socioeconomic impacts – e.g. Nordic regions [9]. • Industrial and post-industrial regions will be disproportionately affected by climate policy; modelling of a Belgian energy tax reduced GDP in industrial regions [87], and rising energy costs may force industrial offshoring [84]. • Post-industrial regions facing "double deprivation" from transition policies, since they are starting from a position of inequality [77]. • Electricity price changes as part of funding low carbon energy infrastructures may exacerbate existing energy poverty (e.g. in post-communist states with inefficient housing stock [83]). • Funding LCT measures may pass through costs to consumers, as in the case of French nuclear decommissioning [10]. • Differential access to subsidies may further impact "low-performing" regions, as in the case of Estonia [77]. • Certain "types" of space (e.g. rural areas) are structurally less able to benefit from subsidies, for instance for EVs [93,94], and urban areas are systematically prioritised [54].
Procedure	Regions may face variation in opportunities to engage with decision-making around low-carbon developments	• Locally unwanted development is more likely to occur in areas of lower perceived resistance, i.e. lower social capital [89]. • Communities affected by a development may not be appropriately consulted due to definitions of the "affected population" being drawn around arbitrary spatial boundaries [102]. • Certain regions and social groups therein may be less able to contribute to local LCT projects (e.g. energy cooperatives) due to the spatially varied distribution of social, financial, and human capital [98–100]. • Citizens' assemblies may provide fora for public input to regional development pathways and LCT planning for their region, as well as enabling a fair representation of views from a cross-sector of civil society [104].
Recognition	Regions have distinct "place identities" and histories which should be acknowledged in the development of regional LCT pathways	• Without recognition of local acceptability, proposed developments are likely to encounter resistance, for instance in local objections to wind energy developments [107] or local preference for coal developments in ex-mining areas (for instance in some regions in Australia [81]). • Place identity should be acknowledged as a potential barrier to LCT measures, for

(*continued on next page*)

Table 2 (*continued*)

Dimension	Spatial justice implications	Case studies
		instance risk-aversity to certain types of energy development such as nuclear energy in Japan [95]. • Perceived place identities may be exploited where locally undesirable developments are allowed by virtue of having been carried out there before, undermining local preference and desired regional development pathways [108]. • Past transitions may render certain types of development more or less socially acceptable [112].

justice may be the more powerful. Tools identified to mitigate low acceptance involve substantive consultation procedures, which are reflected in the body of work on "procedural justice'" [82]. This is reflected in Simcock [117], who draws attention to the importance of perceived procedural justice at the local scale in the case of siting community wind projects.

Just as acceptability was dependent on perceived justice in LCT policy measures, a sense of justice was dependent on the recognition of differential capabilities and responsibilities to decarbonise. As Mayne et al. [96] note "people are more likely to accept climate change mitigation and adaptation policies if they reflect a fair balance of responsibility, capability and need". Mayne et al. [96] and Sasse and Trutnevyte [32] suggest that capacity and responsibility are "equity principles", which go beyond the conventional justice framework of distribution, procedure and recognition [58].

Capability refers to the ability of different regions or actors to do more to mitigate [32]. Responsibility, by contrast, refers to the duty of different regions or actors to mitigate, often reflecting cumulative historic emissions [32]. Whilst it is important to note that capability and responsibility do not always align, in historic perspective developed states that have benefitted from more years of fossil fuel production are generally more able to afford mitigation costs. With the offshoring of industrial production however, states in the Global North may have lower domestic emissions, therefore emphasising the importance of an embodied perspective wherein developed states account for the emissions associated with the goods and services they consume, even if they cannot exercise control over the factories themselves.

A critical debate in the literature is whether capacity or capability is the more appropriate term. Whilst Füssel [86] deem it a "notational convenience", Mayne et al. [96] suggest that capability is "an actor's ability to take effective action to reduce carbon emissions and which therefore includes its legal powers, policy instruments, financial/technical/human/social resources, as well as the trust that other actors place in it to act". By contrast, capacity is the more passive ability of an actor to "cope and adapt" [86]. We refer in this analysis primarily to "capability" given we are addressing the changes required to achieve a low carbon transition, rather than only the impacts of both transition and climate change.

Capability is spatially differential, which can create issues when responsibility for net zero policymaking is devolved to regional authorities of variable power with the same deliverables expected [118]. In the UK, there is significant variation in the ability of different local authorities to both access and implement government funding grants [2]. Local authorities challenged by existing issues of multiple deprivation and socioeconomic inequality will have less operational capability to coordinate low carbon policy measures, reinforcing existing regional inequalities [77]. At the household level, there are similar disparities in capability. For instance in the ability of different households to access subsidies and utilise them [2]; as Sovacool et al. [10] note, "the tenants can't put up solar panels because they don't own the roof". Differential capabilities therefore suggest a need for caution in assuming the power of individual, and voluntary, action [5,96].

Issues of injustice arise where there is a conflict between capability and responsibility, particularly where the most responsible and capable do not act first or go furthest. Indeed, Füssel [86] find that "there is a double inequity between responsibility/capability and outcome vulnerability to climate change". That is, those least responsible and least capable are most vulnerable. There is therefore an ethical rationale in identifying the most capable and responsible to act and allocating duties to mitigate on such a basis. This is reflected at the international scale in the UN principle of Common But Differentiated Responsibility (CBDR), which in full also references "respective capabilities" [66].

Whilst justice may be dependent on the most responsible taking the most action, there is significant controversy in how to determine relative responsibility. Equitable carbon accounting typically considers the cumulative historic emissions of an individual country [119]. There are fewer considerations of responsibility which address the subnational scale however, despite the fact that the intranational dynamic acts as microcosm for the issues playing out on the global stage and international contentions over responsibility-taking.

Issues may arise where those most historically responsible are least capable of decarbonising in the present day (for instance industrial regions), and therefore become vulnerable to contemporary climate policy. Current competitiveness issues and climate policy costs cause financial precarity in industrial regions, hinder investments in mitigation technologies and create instability in the regional employment base. So whilst industrial areas have generated and continue to generate the majority of production emissions, it is debatable whether they bear responsibility or even have the capability for future decarbonisation. In this way the characteristic and historic economic activity of regions has a set of ethical questions for present day climate policy.

4.2.5. *Temporal justice and its implications for spatial planning*

A critical insight from the study sample was the way in which the LCT may interact with existing and historic land use paradigms, and what this may mean for future transitions. This raises critical questions of intergenerational, *temporal* justice and how it intersects with questions of spatial justice.

Cowell [112] argues that historic land use could affect the relative acceptability of proposed developments, noting that "already industrial" areas are likely to be considered more acceptable for further development or even reindustrialisation. This overrides questions of recognition justice which ask what type of *future* development pathway might be preferable for such regions rather than relying on the template of the past. For instance Chateau et al. [120] write of the spatial implications of "sociotechnical imaginaries". Cowell similarly notes that:

> the research shows the powerful tendency of certain categories of land use to reproduce over time, with an industrialised past helping to legitimise an industrialised future, hemmed in very often by societal desires to protect 'pure', rural spaces from such fates [112].

This seems to suggest that there is potential for the replication of existing power structures (in both political and technical senses of the word). This was considered true of both fossil fuel and renewable infrastructures, rationalising the common controversy where wind projects have been proposed in "symbolically clean" rural communities [112]. The distinction drawn in the literature between "pure" and "polluted" land use carries an implicit morality judgement. This ties to the work of Mary Douglas and "matter out of place" in suggesting that there is an ethically "correct" place for pollution [121]. Sayan [8] argue that the "discursive construction of an area as wasteland" results in disproportionate burden being placed on certain communities. This highlights the importance of recognition and procedural justice in

allowing affected regions to "self-determine" their LCT pathway rather than allowing policy precedent to determine what is acceptable. As noted previously, this can be realised through citizens' climate assemblies [104]. The differential treatment of regions based on their land uses becomes a justice issue where certain groups are disproportionately and recurrently affected by burdens of environmental harm.

The sample literature frequently noted the sense of environmental determinism in how regional economies and opportunities are continually shaped by their natural resources. This determinism in spatial justice theory has, as noted, been a source of critique. Regional development theory such as the core-periphery model attempt to explain persistent socioeconomic inequalities between regions [13,94,95]. Other literature in the field of regional studies considers the problem of regional lock-in to certain industrial activities and development pathways [122,123].

Current regional socioeconomic inequalities may result from past policy decisions (particularly spatial planning policy), meaning attention must be paid to historic injustices and spatial vulnerabilities which could be exacerbated by LCT policy decisions. Although many studies were excluded from the sample on the basis of their exploration of green space accessibility (which was deemed a narrow interpretation of "sustainability"), several studies considered how urban planning was a factor in spatial injustice. Planning controls the distribution of environmental goods and bads, and the accessibility of infrastructure and services. This may be a more or less visible phenomenon, for instance in the case of US Superfund sites and their spatial distribution (a cornerstone of the environmental justice movement), or less visibly in terms of access to amenities, differences in costs of living, and vulnerability to climatic extremes [124].

Historic policy decisions were seen as critical in shaping present day opportunity structures and injustice. Extremes in this were indicated by case studies of American cities such as Baltimore [80]. Cole et al. [47] find that there is spatial inequality "across multiple aspects of social deprivation" in South Africa, as "a legacy of the racial segregation of Apartheid". Similarly Cruz-Sandoval et al. [14] discuss the legacy of colonialism in creating unequal spatial forms and therefore perpetuating socioeconomic disparities. The whole systems approach to injustice recognises the importance of considering cross-temporal injustices associated with transition, that is: past injustice, present injustice, and the potential for new injustices to be created alongside transition [125].

This emphasis in the literature highlights the importance in designing spatially just policy to deliver the low carbon transition in a way which recognises and responds to a legacy of past spatial injustice.

4.3. What policy and governance approaches could embed spatial justice in the LCT?

We first consider what challenges exist to the development of spatially just policy, before identifying spatially just policy approaches as suggested by the study sample.

4.3.1. Challenges to spatially just policy

Existing policy has been critiqued as spatially regressive [50,93]. It has also been suggested that LCT policy risks embedding place-based difference and reproducing existing power structures [3]. For instance, in the UK there is competition between regional authorities for inward investment, which is regressive in a context of variable capability between authorities [2]. A sector-based approach to industrial policy further creates issues of regional prioritisation when industries are spatially concentrated; however, there have been suggestions that sector-specific policy can address social inequalities when focussing on foundational industries in already-deprived areas (i.e. when the sectors targeted align with the areas in need of most social benefit) [126]. Similarly, attempts to target specific socioeconomic groups bypass justice issues endemic to certain regions.

There is further concern that policymaking for the LCT could be adversely affected by the spatial and equity assumptions of energy system and energy-economy models used to inform decision-making [6]. There are further issues around transparency and the prioritisation of cost-optimisation approaches [70]. A partial corrective exists in using public or expert surveys to complement and feed into any modelling activity [94], and in the use of "spatially explicit" models [70].

LCT policymaking is further challenged by data and knowledge limitations [12,47,86,127], particularly at the subnational scale [53,128]. Additionally, there are questions over how to quantify or value intangibles such as opportunity costs or environmental harms [6], an activity which is inherently uncertain. Similarly, how indicator frameworks hoping to monitor the relative justice of the transition can account for less tangible criteria such as vulnerability [54,55].

Several studies drew attention to the coordination issues between scales of governance and between regions. This frequently led to a sense of administrative fragmentation, which does and could prevent the effective (and fair) delivery of transition policies [2,7,12,129,130]. Issues also included different definitions of sustainable development between regional and national governments [5].

4.3.2. Spatially targeted policy interventions

To correct the identified shortcomings of policy in reproducing spatial injustices and with ineffective governance systems, several studies noted the potential for more spatially targeted policy interventions to shape context-specific solutions [47,48,51,131–133].

Existing top-down frameworks were viewed as "both economically inefficient and socially divisive" [7]. Demeterova et al. [76] argue that spatially resolved policymaking is more efficient as more cognisant of "regional capabilities". Other studies point to the need for spatial nuance in international or other wide-ranging policies, for instance in the case of a global carbon price [134]. Spatially targeted interventions could be more mindful of recognition justice issues, in identifying the need for individualised development pathways for different regions [76] and the fact different communities each have their own vision of net zero [120]. There is simultaneously a need for cohesion in the direction and pace of travel, but the means to get there is open to debate.

Examples of spatially resolved policymaking include regional target-setting, for instance in California's legislation of GHG reduction targets for its metropolitan regions [119]. An important corollary to any target-setting practices was the need for monitoring via appropriate indicators [11,48,53,84,86], which could be hampered by regional data availability. Others called for interregional redistribution to improve the justice of LCT policymaking, for instance via tax revenues [2,135]. That is, interregional burden and benefit sharing, such as "pro-poor distributive policy" [66]. Several authors argued for greater governance power to be devolved to various scales, including: the regional [2,12,91,132], the city [9], or the community-level [127,133].

Recognising the issue of benefit and burden sharing, several policy tools exist to bridge the gap between the regional "winners and losers" of transition. For instance the use of community benefit agreements (CBAs) which ensure any developments endow the affected communities with financial compensation or "in-kind" benefits [88,89]. The growing embodied injustice movement [44] also represents a mechanism by which to acknowledge the justice issues along the supply chain and close a cognitive gap of accountability between sites of production and consumption (as discussed further in Section 4.3.4).The principle of burden-sharing is enshrined (at least notionally) in international climate policy [6,136], but there are issues surrounding the assumption of responsibility and the ethical basis for allocating this.

In addition to discrete policy interventions, there are a number of governance approaches and paradigms which suggest ways for the LCT to be more spatially just; namely, the localisation or decentralisation movements, embodied justice assessments, and the whole systems approach. Table 3 summarises these approaches and the dimensions of justice and equity that they address.

Table 3
Summary of policy and governance approaches to ensure spatial justice in the LCT.

Policy approach	Justice and equity issues addressed
Interregional redistributions and benefit sharing	• **Distribution:** although a retrospective corrective measure, interregional redistribution (for instance of tax revenues) would rebalance uneven tax bases across regional governments allowing areas to better invest in LCT measures. • **Capability:** this approach recognises the variable financial capital available to different regions, and hence ability to invest in the LCT.
Community benefit agreements	• **Distribution:** where LCT developments have impacts on specific communities, CBAs help to mitigate or at least compensate for these impacts (for instance in the siting of low-carbon energy infrastructures which can be spatially expansive). • **Responsibility:** CBAs mark "responsibility-taking" on the part of the developers, and recognising that communities may not be able to reject proposed developments given the need for socioeconomic development.
Consumption-based emissions policies	• **Distribution:** consumption-based emissions accounting and policy recognises that certain regions face the burden of hosting industrial facilities, whilst their populations are not those driving consumption. • **Responsibility:** emissions policies of this kind ensure that the beneficiary of final consumption must take ownership of the externalities associated with that consumption. • **Capability:** by ensuring that any GHG emissions targets are set on a consumption basis, greater responsibility is placed with the final consumer or beneficiary who may be more able to cover the costs of climate externalities.
Whole systems policy assessments	• **Distribution:** by evaluating the impacts of LCT policies across multiple policy jurisdictions, policymakers can better account for existing socioeconomic vulnerabilities and appropriately target interventions to address these. • **Capability:** this kind of assessment can also identify those who are more able to contribute to the financing of LCT measures.
Regional target-setting	• **Recognition:** target-setting at the regional scale would allow for more context-specific action, and the creation of more nuanced regional development pathways. • **Responsibility, capability:** regional target-setting would recognise the different capabilities and responsibilities of regions to decarbonise, for instance in identifying the historic beneficiaries of polluting activities.
Citizens' assemblies	• **Recognition:** citizens' assemblies to inform low-carbon regional development pathways allow recognition of regional place identities. • **Procedure:** the assemblies allow the representation of views from a fair cross-section of civil society by design. • **Acceptability:** such assemblies allow the relative acceptability of different transition measures in a given region to be openly debated.
Devolution	• **Procedure:** the devolution of clear powers, funding and responsibility to regional governance bodies could give agency to such organisations to effectively coordinate LCT activities at a more nuanced scale. • **Responsibility, capability:** clear devolution of policy powers and funds would allow regional bodies to act on their duty to decarbonise and give sufficient institutional capability to carry this out.
Decentralisation and community governance	• **Procedure:** for some transition measures (for instance energy generation), it may be appropriate to support the role of communities as "prosumers" where they could accelerate the deployment of low carbon technologies. • **Capability:** more support would be required for communities with less social capital or other form of resource to initiate such projects.

4.3.3. Localisation – and democratisation?

The need for the spatial alignment of benefit and burden may also be in part behind the decentralised energy generation movement, which reflects broader interests in polycentric governance as a tool to overcome public good distribution disparities by emphasising local and plural centres of experimentation [13]. The decentralised energy, localisation, or prosumer movements mark a literal closing of a geographic gap between sites of production and consumption, and a local accountability for the externalities of their consumption behaviours [3].

The study sample drew frequent attention to the potential for community-scale governance of LCT measures, but the normative framing of the local as inherently more "just" should be interrogated. Localised governance is frequently advocated for its effective use of local knowledge, greater community ownership of projects and attentiveness to local needs [38,50].

The move towards decentralised energy production is often construed as more democratic [32,51,95,137]. It is seen as particularly applicable in more dispersed or rural populations, and is often relevant for developing nations with less pre-existing energy infrastructure [92]. Emery [138] suggest that more distributed energy resources could be more flexible, cost-effective and provide co-benefits.

However many critics warn of the "local trap", the assumption that local action is intrinsically more effective [2]. Lawhon and Patel [68] indeed argue that attention to the local scale can divert from issues of global responsibility. Similarly there is an argument that localised governance exaggerates issues of variable social capital across communities, with those more capable of self-organization most likely to realise the benefits of the LCT [96]. Where there is a normative expectation of community action this creates issues of justice, particularly when there is downscaled responsibility without downscaled resources [139].

This draws attention to the need for multi-level governance systems with national oversight, mechanisms for subnational redistribution, and flexible implementation at the local scale. There is a similar assumption that any form of devolved governance is intrinsically more "just", which several authors question [44,67,80].

4.3.4. Whole systems justice

The potential spatial mismatch in the distribution of benefits and burdens associated with the LCT raises the question of "whole systems" or "embodied" justice; does progress in the LCT for one region or community result in burden for another, and how is it possible to shape a chain of accountability? Whole systems justice refers to the consideration of justice and ethical impacts across the supply chain for a given product or activity, or across all domains of economic activity [31]; it also considers the potential for injustices across both space and time [125]. Many studies argued that a "whole system" or "integrated" approach to the LCT is more just, rather than treating transition activities as a series of discrete policy areas [11,13,15,58,64,127]. This involves greater cross-sectoral and cross-scalar integration of transition policies to improve fairness [3,77,130]. As Fell et al. [94] note, this is partly due to the greater prevalence of economy-wide decarbonisation targets which demand assessment of distributional impacts beyond the impact of a specific policy, but rather the package of policies required to deliver the LCT.

A whole systems approach is of particular importance for spatial justice, in that certain regions are more vulnerable to multiple

deprivation; in some areas there is layered socioeconomic (dis)advantage. The most deprived regions face overlapping vulnerabilities [2,3,7,48,55,77,94]. This is reflected in the "double energy vulnerability" debate of Robinson and Mattioli [140] addressing energy and transport poverty. A whole systems approach would also better account for issues of cross-scalar injustice [44].

"Embodied injustices" were a growing area of concern, with significant spatial justice implications. Embodied injustice can be considered a form of whole systems injustice focussing specifically on the spatial and ethical implications of supply chains. Whilst whole systems justice draws attention to the different sectors of the economy, embodied justice takes a more "vertical" approach in identifying the implications across space from one given activity or policy. It identifies that there are cumulative injustices along supply chains, that is, injustice may not only occur at or within one spatial scale. Sovacool et al. [4,10] and others question the embodied injustices inherent in the supply chains of even renewable technologies. Droubi et al. [141] call particularly for attention to communities of extractive activities. For instance the ethical implications of smart meter use in the UK, when such a low carbon technology depends on rare earth mineral extraction in the Global South [10]. Sovacool et al. [64] calls this the "spatial externalization of deleterious environmental and social effects". The concept of embodied justice is therefore an attempt to make "visible" the environmental externalities associated with consumption, particularly in the Global North [4], and an attempt to avoid the offshoring of ethical consequence.

Embodied justice is particularly important in the context of transnational corporate actors, and an increasingly globalised business world, in providing territorial anchors of accountability. The UN Guiding Principles on Business and Human Rights identify that private actors have a duty of care regarding their operational and supply chain impacts [96]. Zuindeau [142] similarly highlight the importance of taking an international perspective to deal with questions of transnational accountability. An embodied justice perspective may be supported by carbon accounting methodologies such as carbon footprinting. Consumption-based emissions accounting identifies the cumulative impacts along the supply chain associated with the consumption of a good or service. In this way, the mainstreaming of currently alternative carbon accounting frameworks could improve national responsibility-taking in addressing the emissions associated with domestic consumption.

To close the cognitive gap between sites of production and consumption, acknowledge the environmental externalities inherent in consumption, and create accountability, Healy et al. [44] suggest that energy law and policy should incorporate embodied injustice concerns. In practice this could mean cooperative policies such as international carbon pricing [9].

Similarly, the majority of carbon accounting frameworks employed in national policy are based on territorial or production-based accounting. This form of accounting carries an implicit bias against industrial regions with higher direct emissions, and the regional economies that are supported by large energy and employment-intensive industries. This raises the question of whether responsibility should lie with the producers or consumers. Furthermore, industrial areas in developed states often face a double burden of existing socioeconomic precarity (as a legacy of past deindustrialisation and global market pressures), as well as new climate policy costs (for instance the UK steel industry requiring government loans to pay its Emissions Trading System costs). In global terms, production-based accounting systems in developed states essentially act to transfer responsibility to developing states [134]. An embodied justice perspective might therefore relocate responsibility to the end consumer.

In this way, by taking a broader perspective across scales and stages in the supply chain, a more comprehensive account of the potential justice issues resulting from the LCT can be built, resulting in more spatially targeted policy interventions.

5. Conclusions

This review aimed to explore what could be considered a "spatially just" low carbon transition, and responds to a growing body of theoretical and empirical literature in this area.

Our first research question considered the spatial scales adopted in LCT studies. This is necessarily complicated by questions around the "relational" quality of space and uncertain definitions of "scale". There was a consensus critique of the use of national scale assessment exclusively, with proposals for multi-scalar approaches to more effectively identify issues of interregional injustice. A central difficulty in assessing spatial justice was determined in the dependence on both the choice of spatial disaggregation and of the metric used to quantify injustice.

The second research question aimed to evaluate how spatial justice issues were presented (explicitly or implicitly) in assessments of the LCT. Whilst a large part of the literature considered distributional justice issues, a growing body of work explored the important issues of procedural and recognition justice. Particular contributions from the review include highlighting the influence of *perceived* justice on levels of acceptability in transition measures, which was in turn predicated on a sense of fair "responsibility-taking". Norms in policy and carbon accounting frameworks were seen as important in shaping how responsibility and capability were assessed, with the risk of disproportionate burden being placed on industrial production sites rather than the sites of consumption, emphasising the importance of a whole systems or embodied justice perspective, which informs an important future research agenda.

The final research question responded to these manifold justice issues, by exploring the policy and governance approaches which could embed principles of spatial justice in the LCT. Though descriptions of specific policy tools are on the whole limited, several mechanisms were identified such as community benefit agreements or interregional tax redistributions to more effectively share benefit across space, as identified in the work on distributional justice. Or the use of citizen climate assemblies to guarantee fair consultation and representation to address issues of procedural and recognition justice.

Despite being a review, the analysis poses a novel contribution to the literature is comprehensively synthesising the spatial justice issues inherent in the LCT. The whole system and interdisciplinary approach also overcomes issues of siloed social or technical research in the literature, or a limited focus on one aspect of transition (for instance employment). Though the inherent bias towards case studies in the Global North has been noted, the review has highlighted how spatial justice issues may appear internationally. A key strength of review articles is in their identification of research gaps, and avenues for further research [38]. The studies were predominantly centred on developed nation case studies, meaning there is a critical research gap in exploring the implications of spatial justice for developing states; this may be due in large part to the broader landscape of research funding, a problem endemic to climate research [45,137]. There is therefore further scope to explore how issues of spatial justice manifest in different country contexts as a result, particularly focussing on the types of justice issues facing regions in the LCT, given states are at very different stages of transition.

Further consideration should also be given to the "politics" and social construction of scale, and how this may alter assessments of spatial justice (for instance in identifying where power in LCTs lies). The whole systems and embodied justice literature was seen to fill a key gap in resolving some of the geographic public good gaps between sites of production, consumption, benefit and burden, by shaping a sense of cross-scalar accountability. This is a research space that would benefit from further empirical analysis.

In practice, there is strong need to move beyond accounts of injustice to substantive policy tools which can embed spatial justice. A basic policy advancement which is already occurring in some parts of the world is the recognition that all policy has a spatial dimension, whether

explicit or not. This supports calls for policy evaluation to keep pace. This is significant also in that transition is not a "future" event, but a current process, and one already having disparate and inequitable effects on nations, regions and communities.

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.

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Appendix A. Supplementary data

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