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Policy-relevant insights for regional renewable energy deployment

Carla De Laurentis[1*] and Peter J. G. Pearson[2]

Abstract

Background: The paper explores how regional actors engage with energy systems, flows and infrastructures in order to meet particular goals and offers a fine-tuned analysis of how differences arise, highlighting the policy-relevant insights that emerge.

Methods: Using a novel framework, the research performs a comparative case study analysis of three regions in Italy and two of the devolved territories of the UK, Wales and Scotland, drawing on interviews and documentary analysis.

Results: The paper shows that acknowledging the socio-materialities of renewable energy allows a fine-tuned analysis of how institutions, governance and infrastructure can enable/constrain energy transitions and policy effectiveness at local and regional levels. The heuristic adopted highlights (i) the institutions that matter for renewable energy and their varied effects on regional renewable energy deployment; (ii) the range of agencies involved in strategically establishing, contesting and reproducing institutions, expectations, visions and infrastructure as renewable energy deployment unfolds at the regional level and (iii) the nature and extent of infrastructure requirements for and constraints on renewable energy delivery and how they affect the regional capacity to shape infrastructure networks and facilitate renewable energy deployment. The paper shows how the regions investigated developed their institutional and governance capacity and made use of targets, energy visions and spatial planning to promote renewable energy deployment. It shows that several mediating factors emerge from examining the interactions between regional physical resource endowments and energy infrastructure renewal and expansion. The analysis leads to policy-relevant insights into what makes for renewable energy deployment.

Conclusion: The paper contributes to research that demonstrates the role of institutional variations and governance as foundations for geographical differences in the adoption of renewable energy, and carries significant implications for policy thinking and implementation. It shows why and how policy-makers need to be more effective in balancing the range of goals/interests for renewable energy deployment with the peculiarities and specificities of the regional contexts and their infrastructures. The insights presented help to explain how energy choices and outcomes are shaped in particular places, how differences arise and operate in practice, and how they need to be taken into account in policy design, policy-making and implementation.

Keywords: Renewable energy, Materiality, Regions, Italy, UK, Renewable energy policy

Background

The development, application and proliferation of renewable energy technologies (hereafter, RE) are part of a shift underway in energy systems, not least because of the growing urgency of achieving net-zero greenhouse gas emissions [1, 2]. Because such transitions work against incumbent, widely locked-in fossil fuels and associated

*Correspondence: cdelaurentis@cardiffmet.ac.uk
[1] Cardiff School of Management, Cardiff Metropolitan University, Llandaff Campus, Western Avenue, Cardiff CF5 2YB, UK
Full list of author information is available at the end of the article

technologies, institutions, markets, cultural meanings and user practices, replacing fossil fuels with low-carbon alternatives implies a prominent role for policy and policy-makers [3–5]. While some of the most significant decisions to steer energy systems are made at the national level [6], most challenges surrounding energy infrastructure provision and governance simultaneously involve other spatial levels, as energy infrastructure is embedded in specific territory, even as it organises flows for other, wider spaces [7]. Accordingly, 'the geographical conditions of possibility for energy system transformation are now emerging as a compelling public policy challenge' [8: 1038]. Besides, current configurations of energy flows have deep historical roots and are closely entwined with the overall development trajectory of territories. This history and associated path dependence mean that efforts to accelerate the sustainable transition to greener energy systems need to start from a clear appreciation of these particularities [9].

This paper contributes towards the acknowledgement of the growing importance of the regional scale in energy transition by further investigating how regional[1] actors engage with energy systems, flows, infrastructures, people and policy-making, to meet particular goals. The paper engages directly with growing literature that is closely attuned to understanding the socio-material, territorial and scalar characteristics of energy transitions [10–14]. Agreeing with [15], we argue that further engagement with debates about the 'socio-materiality' of energy can enhance our understanding of the critical success factors that can influence regional energy transitions. The paper does so, by stressing the influence that socio-material forms of energy exert on energy institutions, infrastructure and governance [16–19], providing some further insights on how policy-making towards energy transitions is shaped by spatial contexts.

The paper draws together insights from a research study conducted between 2014 and 2018 that examined the mechanisms that lead to the effective diffusion of RE technologies and influence their spatial deployment differentials (how and where these technologies might be deployed). By adopting a comparative case study analysis and investigating how specific renewable resources become realised in some regions and not in others, the paper offers a fine-tuned analysis of how these differences arise and operate in practice, highlighting the policy-relevant insights that emerge.

[1] The paper uses the term 'regions' to describe territories smaller than their state and possessing significant supra-local governance capacity and cohesiveness.

The paper, in "The regional development framing of renewable energy deployment and policy" section, is situated within the literature that attributes an increasing significance to the sub-national level of the region as an important site for action to promote low-carbon energy systems. "The socio-materialities of energy transitions: from urban to regional" section follows with a review of selected literature that foregrounds the links between the materialities of energy and their implications for the governance and socio-spatial constitution of energy systems and for policy-making and policy choices. "Methods" section discusses the research design and data collection methods, and "Results from the analysis of the case studies" section presents the empirical evidence, examining the differences that have emerged among the case studies investigated. "Discussion" section comprises two parts: "Discussion 1: regional institutional settings, governance and policy-making, and infrastructure issues" section discusses the parts played by institutional settings, regional governance and policy-making, and infrastructure issues; and "Discussion 2: policy-relevant insights for regional renewable energy deployment" section draws together wider policy insights and implications of giving consideration to the socio-material forms of energy in a regional context. "Conclusion" section summarises the analytical and empirical contribution made to the energy geography and policy literature.

Situating the research

The regional development framing of renewable energy deployment and policy

There has been increasing attention to how a better understanding of the spatial dimensions that shape energy systems offers insights into factors that influence energy transitions. While the geography of energy transitions continues to mature [20, 21], a variety of contributions have emphasised the role that local and regional institutional settings play in influencing the pace and scope of sustainability transitions [22–25]. Also, a substantial body of literature has focussed on innovation and local/regional capabilities for developing new growth paths [26, 27], in which regions emerge as significant sites for innovation and experimentation [28–32], where objectives other than climate change, such as employment, may be achieved [33]. And it has been shown how differing regional industrial specialisations, natural resource endowments and local/regional institutional set-ups can promote differences in approaches to and outcomes of energy transitions and the policies that affect them [34, 35].

These analytical approaches to a regional development framing of RE emphasise how the varied combinations of assets—human, institutional, industrial, infrastructural

and material—have shaped regional energy transitions in many ways. Similar regulatory settings (e.g. subsidies and incentives) can work in different ways at regional and local levels [36] and local and regional development governance, visions and policies can play important roles in supporting or constraining energy regional transitions [37].

Regional differences in the incentives and capacities to increase RE deployment draw attention to the uneven distribution of innovation processes and how they are influenced by institutions, actors and networks at this spatial level [26]. Differences in institutional contexts for regional innovation and energy governance have become important influences on regional energy transitions. Borrowing from new-institutionalist approaches [38], regional energy infrastructure systems, including transmission and distribution networks, are influenced by and interact with institutions, broadly understood in terms of the formal regulations (e.g. connection rights, transmission charges and location pricing, historical rules and institutions favouring centralised electricity infrastructures and utilities) and informal societal norms that regulate the behaviour of economic actors (e.g. energy imaginaries). Such institutional arrangements shape energy infrastructure-related decision-making, overall energy and RE policies and can be associated with different governance choices [18, 39, 40]. Although these institutional arrangements reflect a dominant model of national-based policy formulation (e.g. in terms of subsidies, price signals, capacity markets and the rules/codes for planning and operating connections to the grid), supported by an overarching energy security and access agenda [41] that sees energy infrastructure as a national 'sustainable development priority' [42: 1226], numerous contributions have emphasised the role of institutional variations as foundations for geographical differences in the adoption of RE [24, 36, 43–45].

Thus, the regional level has been acknowledged as an important governance scale where many energy and environmental responsibilities and policies are implemented and realised [46–48]. For example, regional development strategies have increasingly focussed on the economic development opportunities of RE technologies as both a response to environmental problems and as way of advancing regional development [26]. Differences therefore have arisen in: (i) regional institutional arrangements of energy governance (e.g. regional energy planning in terms of RE targets, siting and consenting powers), as shaped historically by EU and national legislation and as they may evolve after Brexit [15, 49, 50]; (ii) the actors involved (e.g. regional governments, regional actors and their networks) [35, 51]; and (iii) how they exercise such governance, via the establishment of visions, the framing of economic development opportunities and entrepreneurial agency [52, 53].

Regions therefore show varying capacities for agency and influence within a national context of centralised energy governance. Thus, RE innovation processes, including RE deployment—and the policies associated with it—are not just the pursuit of national governments and incumbent actors (e.g. energy companies, utilities and regulators), but also involve a host of regional actors and social and political interests that can mobilise different visions, instruments and responses in connection with some of the mandates that they might hold in various policy areas (e.g. land-use, planning, transport and mobility, social welfare and economic development) [54, 55]. These areas become a means through which local and regional actors can influence energy infrastructure change. Consequently, more attention needs to be devoted to understanding not only regional actors' roles in establishing, contesting and reproducing institutions, expectations and visions, but also the growing significance of the regional scale as a form of energy space [53, 56].

To do so, we suggest that engagement with the literature that is closely attuned to understanding the socio-material characteristics of energy transitions and territories [8, 10, 12, 14] is fruitful here. Our objective, in the next section, is not to offer a comprehensive literature review, but instead to identify from it key areas under which understanding and analysis of the role of regions and regional policy-making in RE deployment can be enhanced.

The socio-materialities of energy transitions: from urban to regional

Emerging literature that seeks to understand the socio-material characteristics of energy transitions lends well-formed conceptual tools to the task of unravelling the relationship between energy transitions and their geographical implications [8]. Here, we discuss briefly these contributions and then move to highlight how these approaches can be helpful in addressing questions of energy decision-making, how competing interests are mediated, and what complexities can undermine/empower regional agency.

The urban literature has been useful in bringing out the wider co-constitutions of the material, political and socio-technical configurations of energy systems [57, 58], revealing insights that can help unpack the relation between regions and energy transitions. The argument here is that expanding these conceptual tools to a regional perspective offers an additional frame to examine questions around energy infrastructure and agency in spatial and political terms.

Investigating energy infrastructure systems as socio-material configurations of physical and immaterial elements, and how they relate with territories, has gained traction in analyses of how energy (and other) infrastructures are 'interwoven with the changing material, socio-economic and ecological development of cities and urban regions', with urban areas considered 'centres of demand and exchange within multi-level flows of power and energy resources' [59: 9]. The emphasis on weaving infrastructures and services into scales by exploring the socio-spatial and material forms of infrastructures gave rise to a research agenda that investigates the co-evolving relationship between urban change and energy transitions [58]. Urban energy transitions are seen, therefore, as a way of taking seriously both the materiality of urban energy flow—its socio-technical and physical characteristics—and 'the varied contrasting, sometime competing, political projects for which it works' [58: 1358]. These contributions stressed how the spatial and material aspects of energy are important influences on urban development processes and energy landscapes, and how they have become one of the prominent conceptual lenses used to understand the co-evolution of energy provision and urban development [17].

While energy systems can be understood as 'geographically spread socio-technological configurations' [60: 720], that involve different technologies, relations, capacities and power relationships, the urban literature has been useful in bringing in the wider co-constitutions of the material, political and socio-technical configurations of energy systems. This denotes a growing interest in: (a) the mutual constitution of social and physical spaces [16, 61]; (b) the importance of specific configurations of agency in shaping such relations [62]; and (c) the opportunities it offers for 'grasping the type of participation they foster and the various political tropes they convey' [14: 27].

In this respect, energy socio-materialities become important in that they point towards the role of the historical legacies of urban/local energy infrastructures [63], the proximity to geographically fixed resources (e.g. geothermal energy and its relevance for promoting urban heat networks), and the pre-existing transportation or distribution infrastructure required to harness the renewable resource into a marketable form of energy [16], and the importance of governance in promoting those material energy assets and their use [62]. These contributions have expanded our understanding of energy infrastructure and its relations with the urban realm and the wider spatial organisation of agency. Refocusing the analytical lens to the regional level offers an opportunity to further investigate the multitude of actors/interests involved in RE infrastructure financing, production and advocacy. Moreover, it recognises how the structures and histories of regions themselves shape decisions about infrastructure development, including the disruption or perpetuation of socio-economic patterns. Partly by building on these urban-level insights, there has been a growing number of studies of how these socio-materialities have influenced regional energy transitions (in Italy [16], in Germany [15], in France [64], and in the UK [65]). They have shown the significance of the co-production of material and social phenomena in energy transitions and identified the unevenness of RE deployment processes.

These contributions share a focus on socio-technical transitions and the importance of the local, institutional and political contexts, and propose ways to reflect on the contextual construction of RE sources. Engaging with this debate, this paper employs the approach to the analysis of socio-material dimensions of RE used in [16], as this framework has the advantage of explicitly drawing out the mutual constitution of social and physical spaces and the mediating factors between energy infrastructure and energy governance and policy. A further merit is that it considers both physical infrastructure systems and the 'rules of the game' [38: 5] in energy transitions; this offers an addition to current energy transitions literature which tends to look at energy systems only from a socio-cultural perspective.

[16] identified three interrelated 'socio-material dimensions' of RE, positing that these both directly influence RE deployment potential and help understand how, through political-economic and cultural processes and policy-making, apparently 'physical' RE resources come to be socially constructed as exploitable, marketable energy resources [13]. These socio-material dimensions are:

1. *RE sources as potentially deployable sources of energy that interact with current land-based resource use* The processes involved in the physical, technical and socio-economic appraisal of the resources, including their extent and potential (or the 'quality'); and how these processes interact with the resources' contextual conditions (e.g. land areas required and their location, land-use preferences, land-use ownership, land-use protection and land cover);
2. *The nature and content of discourses, narratives and visions for RE deployment* The visions and narratives actors use to promote their interests and influence RE deployment, partly by framing or reframing debates on priorities around the deployment of new energy sources and their potential contribution towards the region's objectives and status;
3. *The nature, extent, management, and regulation of built infrastructure requirements for RE delivery and the power to shape such infrastructure* The ways in

which renewable deployment outcomes are influenced by the physical characteristics of renewable resources and the necessity of a robust infrastructure for RE delivery. This includes how the pre-existing built infrastructure and its regulation and management may enable or limit RE potential and become' sites for political contest and change' [66], as well as any new infrastructure requirements, including the 'hard' and 'soft' transportation or distribution network developments required to harness the renewable resource into a marketable form of energy. Acknowledging that energy infrastructures have 'politics or create political effects' [19], also highlights the importance of investigating energy infrastructure decision-making processes—including the power and influence of different actors.

Our argument here is that these socio-material dimensions can help to develop a richer understanding of the relationships between energy-related institutions, governance and policy-making, at regional and other levels, and infrastructure issues.

Institutions, governance and policy-making, and infrastructure issues

While research has highlighted the central role of institutional variations as foundations for geographical differences in the adoption of RE [24, 36, 43–45], the approach used in this paper highlights the relevance of the institutions managing electricity and the regulatory frameworks that can influence RE uptake. Here we refer to the 'formal regulations, legislation and economic systems as well as informal societal norms that regulate the behaviour of economic actors' [67: 7]—that matter for RE and to the varied effects that they can exert on regional RE deployment. This paper asks whether and to what extent RE policy-making and uptake at the regional level is influenced by institutions, such as connection rights, transmission charges and location pricing, historical rules and institutions favouring centralised electricity infrastructures and land-use, as well as infrastructure imaginaries related to energy security priorities. While the national level plays a key role not only in promoting RE deployment, but also in regulating infrastructure in ways that reflect the increased attention to electricity network security of supply following increases of RE capacity, it matters also to unpack the types of institutions regional actors can influence and how they go about doing so.

Relevant institutions embrace policy frameworks and actions, including RE strategies, decarbonisation plans, RE target setting, and providing financial and institutional support to particular energy sources and modes of energy provision that might also influence actors' ability to take part in local energy transition governance (e.g. community energy). We refer here to how questions of governance relate more broadly to the socio-material dimensions of RE highlighted above. We argue that the socio-material dimensions emphasise the range of agencies that may be involved in strategically establishing, contesting and reproducing institutions, expectations, visions and infrastructure as RE deployment unfolds. These dimensions show how socio-material aspects of energy systems can have significant influences on system governance, as different local and regional socio-material characteristics promote variety in energy transitions and shape transition governance in manifold, and sometimes uncoordinated ways [17].

Additionally, analysis of the socio-material dimensions shows how higher shares of RE tend to amplify the need for transforming the electricity infrastructure—both at transmission and distribution levels [68]. Much infrastructure transcends both local and national administrative boundaries. Energy infrastructure, and its regulation, functions across territorial units that seek to govern energy relationships and deliver energy-related collective goods [69]; hence regional energy transitions will be influenced by the physical networks that distribute energy and, at the same time, by actor networks and their interactions [70]. Adding a socio-material lens allows to capture how both types of networks can influence regional energy transitions.

Connecting RE sources to the existing electricity transmission and distribution networks has required both the construction of new lines and the upgrading of current networks. Hence, managing grid capacity and infrastructure upgrades becomes a site-specific issue that implicates local and regional actors in steering infrastructure requirements. This goes beyond planning approvals for individual projects and considers how energy networks can be more strategically reconfigured, to better foster decarbonisation (in terms of, for instance, the relations between demand centres and RE sites, funding for local infrastructure and possibilities for local energy infrastructure development). The approach used here thus opens up questions of agency/territorial responsiveness and shows how the challenges surrounding energy infrastructure provision simultaneously involve various governance scales [7]. It therefore adds to a relational perspective on space and energy by understanding energy-related activities within a particular space (the sub-national level of the region) and the connections and interactions between spaces [10].

Table 1 outlines how the socio-material dimensions of RE might interact with the three factors (institutions, governance and policy-making, and infrastructure) at the regional level, identifying the aspects that potentially

Table 1 How the socio-material dimensions of RE might influence regional institutions, governance and policy-making and infrastructure

Socio-material dimensions of RE	Institutions	Governance and policy-making	Infrastructure issues
Renewable energy sources as potentially deployable sources of energy that interact with current land-based resource use	*Spatial planning and land-use* Land-use preferences, Planning and land-use law/rights Social attachments to the environment and the re-appraisal of the landscape, e.g. strategies that draw upon siting criteria to create new representations of development opportunities, such the creation of spatial zoning with presumption in favour of RE deployment	*Regional agency and spatial planning* The regional level often has responsibilities for and some authority over regional economic development and planning and for the construction and application of mapping methodologies, e.g. spatial planning Negotiation and weighing of different environmental values against RE targets vs. land-use policy traditions and values Limits to expansion and pressures for and regional responses to RE deployment Regional renewable companies might hold research or land-use permits and have the know-how to negotiate/understand local planning issues	*Transmission and distribution infrastructure renewal* Infrastructure networks are connected (transmission and distribution networks) within specific territories and there interconnections between them Grid capacity and infrastructure upgrades become a site-specific issue that requires planning approvals and can meet with local opposition
The nature and content of discourses, narratives and visions for renewable energy deployment	*Shared visions and binding expectations* Which characteristics of the resource become incorporated into mapping and which get excluded and the extent to which (these spatial representations) are accepted or resisted by different actors Identity and cultural influences: e.g. anti-nuclear and alternative energy movements	*Target/aspiration settings and legitimisation* Locations presented as sources of inward investment ('open for business')/simplification of legal and regulatory frameworks to support ambitious deployment policies Coherent narratives provide legitimisation of a particular process of regional development and RE and are used as a conduit and a way of communicating the articulation of particular RE development paths	*Energy security and access* Investments in transmission and distribution networks may be legitimised as a 'sustainable development priority' Visions for RE might ignore the grid; treat existing grid capacity as 'firm', constraining RE location; or assume that extra grid capacity will materialise to follow new generation capacity
The nature, extent, management, and regulation of built infrastructure requirements for RE delivery and the power to shape such infrastructure	*Regulation and standards* Transmission charges (and location pricing) Connection rights/rules Historical rules and institutions favouring centralised electricity infrastructures and utilities	*Regional agency and economic development* Attracting technology developers due to site availability for testing and experimental activities; potential sites are promoted for demonstration projects and experimental platforms (e.g. smart grid and storage) Existing local economic and technological structures, knowledges and competences are mobilised through the purposive actions of agents, resulting in the local emergence of new paths	*Local infrastructure development* Centralised power supply vs. decentralised; demand centre and RE sites Ability and willingness to provide funding for local infrastructure development (e.g. production, distribution and storage) Possibilities for and development of RE-based heat networks

explain regional differentiation in RE deployment and policy strategies and the choices that influence them. The heuristic approach demonstrated in the table shows, for example, in the intersection of the first row and column how the socio-material dimension relating to the appraisal of RE resources brings to the fore the role of institutions that relate to land-use policies [71] and how sufficient potential development space can be identified, at local and regional levels, to deliver RE capacity [72]. Hence, spatial planning approaches and policies 'for' RE can be created, at different spatial levels, and utilised with a variety of purposes—aiding and accelerating RE expansion, reducing adverse impacts, or sometimes curtailing RE expansion [73].

Similarly, shared visions and expectations can promote and influence RE deployment, partly by framing or reframing debates on priorities around the deployment of new energy sources and their potential contribution [74]. Hence visions and imaginaries and the policies that translate them are shaped by the local/regional contexts, interests, priorities of those responsible for producing the vision(s) [75]. Moreover, electricity network capacity is integral to the exploitation of RE resources [76]. Hence, the pre-existing transportation or distribution infrastructure required to harness renewable resources, the rules that regulate them, and the way in which infrastructural renewal is governed and financed have an important role in enabling or limiting RE potential [76].

For illustrative purposes, we have outlined how the three row dimensions in Table 1 might intersect with the institutional factors in the first column. We use the interactions shown in the other cells in the table in a similar manner to help analyse and interpret our data.

The remaining sections of the paper show, drawing from case study research, how the framework adopted here allows for a fine-tuned consideration of issues related to institutions, governance and policy, and infrastructure, and how they can be addressed together, thus facilitating the identification of the wider policy implications for RE promotion and development in particular regions.

Methods

This section briefly describes the design of the broader study from which this analysis is drawn, and the rationale for data collection and analysis. For reasons discussed below, the study used a case study research design [77] which was judged helpful to tease out different contextual conditions (for example, examining the influence of institutions is highly contextual [78]: 'since social, cultural and institutional forces vary considerably across territories, the geographical context of these factors should provide critical input' [79: 59].

Additionally, it was judged important to analyse case studies both within and between two countries as carefully applied comparative methodologies (e.g. cross-regional and transnational fieldwork) can aid in identifying the influence of context and enhance the validity and transferability of research findings [80, 81]. Furthermore, comparative analysis in energy research '(..) can more rigorously generate and test hypotheses across multiple areas, resulting in stronger evidence through a convergence of findings, and a wider applicability of result(s)' [82: 13]. None of which is to deny the epistemological and methodological complexities and challenges associated with the practice of comparison, including the problem of equivalence (i.e. what is common and what is different?) [83]. Nevertheless, it is a practice which '… continues to be an indispensable resource to respond to problems of natural and social knowledge' [83: 822], partly because in the case of cross-national comparisons, 'there are certain properties that make States comparable to each other' [83: 834].

Here, the essence of comparison—and that of the comparative analysis conducted—revolves around the investigations of differences and commonalities among the regions and their RE deployment processes [84]. Consequently, the choice of method was driven by the need to understand and investigate complex and multifaceted phenomena and the way they unfold in specific geographical contexts. This required an intensive and detailed examination that other methods, such as those that require quantitative empirical categorisation, do not allow. Consequently, after considering these alternatives, it was decided to perform a comparative case study analysis of regions in two countries, Italy and the UK: in Italy, following a scoping exercise [16], Apulia, Tuscany and Sardinia were selected, and in the UK the two devolved territories of Wales and Scotland. Apart from the reasons cited below for the suitability of the comparison, the selection had the practical and cultural advantage that the first author has lived and worked in both countries and is fluent in both languages, which facilitated access to and the interpretation of spoken (interviews, conversation) and written materials and other data.

While both Italy and the UK have been subject to similar pressures from European and international regulatory frameworks and have introduced targets for RE and financial and legislative incentives for its expansion, they were selected because there are significant differences between them and between their regions in terms of RE deployment. In both countries, a process of devolution of power has enabled diverse approaches to emerge in support of RE. These countries show differences in their institutional make up and governance, being often seen as an example of a liberal market economy (UK) and as

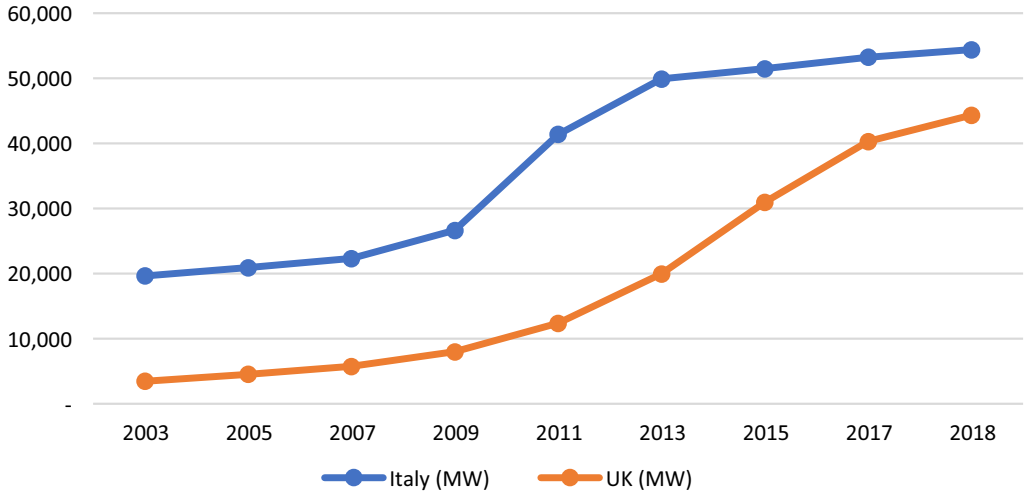

Fig. 1 Renewable electricity capacity (MW) in Italy and the UK. Sources: GSE [87], BEIS [88], BEIS [89]. Italian data for 2018 are estimated

a variation of a coordinated market economy (Italy) [85]. These differences have affected energy policy preferences and influenced RE policies, shaping the adoption of RE technologies [18, 40, 86]. Hence, devolved territories in the UK were selected in terms of their asymmetry of powers and ambition for RE deployment and in Italy in terms of regional diversity and resource endowment, increased autonomy of action and governance capacity over energy. Both Italy and the UK, under EU targets and international regulatory frameworks, were challenged to achieve a significant increase in the deployment of RE and have put in place support incentives to promote deployment. These commitments reflected the characteristics of each country's energy system (e.g. privatisation in the UK and Italy's fossil fuel import dependency) and different resource endowments (with a focus on solar and onshore wind in Italy and onshore and offshore wind in the UK).

Due to the prolonged absence of a national energy strategy and, in particular, a clear roadmap for RE, RE deployment in Italy occurred mainly through 'market forces which were aimed at exploiting resources favoured by support mechanisms that ensured high returns for large-scale investments (UR T).[2] In the UK, the overall design of RE support schemes has reflected the UK government's commitment to reducing greenhouse gas emissions while minimising government intervention in markets, and seeing competition as a key element to drive costs down. The two countries have displayed great variations in the number, type and distributions of RE installations, which are particularly evident by region/devolved territories.

Figures 1, 2 and 3 summarise these differences. While the Italian central government shares responsibility for energy policies with regional governments, in the UK energy policy is a reserved function, much of which is not devolved. Yet, elements of devolution and local government reform have allowed the emergence of a degree of regional and local governance of RE in the UK, with significant institutional differences across Wales, Scotland and the rest of the UK [25, 50]. In Italy, a process of multi-level energy governance characterises the Italian energy system. Energy production, transportation and distribution are subject to concurrent legislation between state and regions (Art.117, Italian Constitution). In the UK, the main policy-making powers and capacity lie in Westminster. Scotland's energy policy is 'executively devolved', which gives Scottish Ministers full control over major consents and planning, onshore and offshore, and some operational control over market support systems. In Wales, the Welsh Government has the fewest powers (the most relevant being planning policy and overseeing planning consent). All the devolved governments have responsibility for discretionary economic development funding for energy-related projects. These and other similarities and differences within and between the two countries and their regions were judged to make them appropriate subjects for comparative analysis.

[2] The code here signifies interview data (see below). The material from the interviews is attributed to the organisation but not the respondents, to protect their anonymity (Appendix 1).

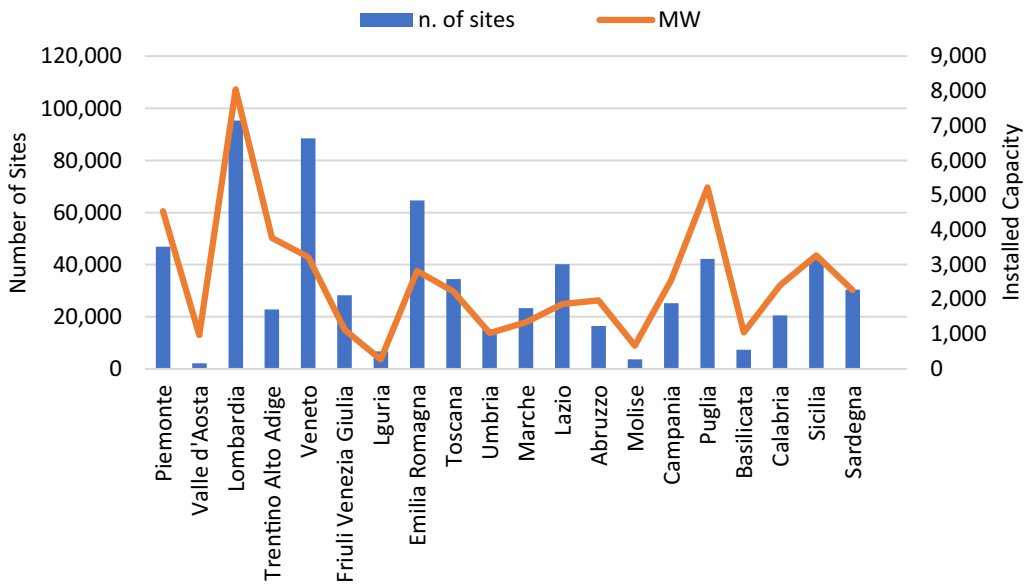

Fig. 2 Regional distribution of renewable electricity (n. of sites and MW) in Italy (2014). Source: GSE (2016)

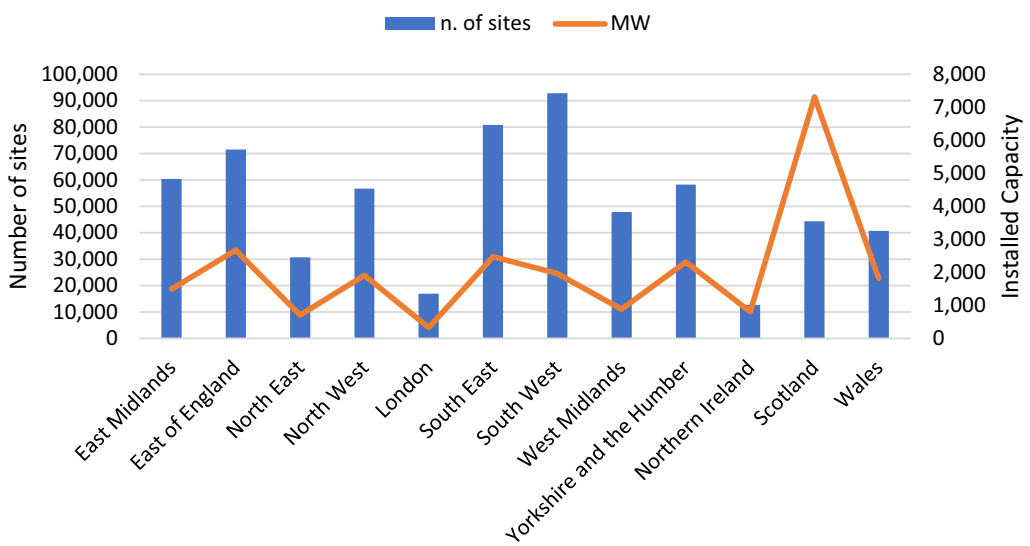

Fig. 3 Regional distribution of renewable energy (n. of sites and MW) in the UK (2014). Source: BEIS (2014)

To perform the comparisons and elicit the insights relating to policy, it was judged appropriate to obtain data via documentary analysis and 35 extensive in-depth expert interviews across the two countries and their regions, carried out between April 2014 and December 2015 [16]. The documentary analysis included an extensive critical review of the academic literature, press reports and national and regional policy documents associated with the greening of energy systems. The interviews involved stakeholder participants from both Italy and the UK, chosen from different institutions and organisations involved in RE systems, a selection assisted by 'snowball' recommendations. These included policy-makers, regional and national government representatives, organisations that supported innovation and RE development (e.g. development agencies), firms, and private and research organisations. The interviews offered the opportunity to collect more detailed information about recent RE deployment and policy frameworks and decision-making at national and regional levels and

explore the role of regional actors and policies in promoting RE deployment. The interviews explored actors' activities that are often not documented and probed their perceptions and narratives around RE deployment and policy-making. The data generated from the research, both in the form of interview transcripts and secondary documents, were organised under thematic summaries, and combined under analytical categorisations, including:

- Regional responses to pressures, targets and existing constraints on RE deployment;
- Renewable deployment and opportunities sought for renewable resource exploitation;
- Policy perceptions of RE support and geographical scale of relevance;
- Barriers to current and future deployment of RE and the policy strategies adopted to address them.

For each case, we traced the socio-material dimensions of RE and teased out how they linked to the institutions, governance and policy, and infrastructure categories presented in the columns of Table 1, and how they influenced or were influenced by policy issues and choices. In "Results from the analysis of the case studies" section, we present the differences in regional implementation of RE that emerged from the case study analysis, discussing them under the three socio-material dimensions. We then discuss their relations with institutions, governance and policy, and infrastructure, with an emphasis on policy issues and choices. "Discussion" section focuses on a discussion of the resulting wider policy-related insights.

Results from the analysis of the case studies

In this section, we first organise the discussion around the three dimensions and provide examples of how RE deployment and policy-making has been influenced in the case studies investigated and the differences that emerged. We then discuss how these socio-materialities of RE enable a more fine-tuned analysis of how institutions, governance and policy, and infrastructure have interacted with policy-making, and so have enabled or constrained RE transitions in the cases investigated.

RE sources as potentially deployable sources of energy that interact with current land-based resource use

As suggested, the first socio-material dimension used to identify differences across regions relates to the processes involved in the physical, technical and socio-economic appraisal of the resources and how these processes interact with the resources' contextual conditions. This occurs via the iteration between spatial resource assessment, land-use and land protection and negotiation among conflicting land-use interests. Consequently, the devices used to frame such negotiations become highly important.

The processes of weighing resource potential and different environmental values against RE targets are often articulated through deliberation between national, regional and local stakeholders. Spatial planning therefore can reflect the capacities and willingness of governments to render land available for RE development and to manage social responses [50]. In both Italy and the UK, the regional (and local) levels are tasked with weighing resource potential and different environmental values against RE targets.

In Italy, the national government was set to provide, following Legislative Decree 387/2003, a set of guidelines for the siting of RE plants, under the principle that RE installations were considered of 'public utility, urgent and could not be deferred' (NG IT). However, these guidelines were not issued until 2010, seven years later than planned. This vacuum allowed a great variety of spatial planning approaches for RE to develop at the regional level. Consequently, some regions became more amenable to large-scale development, while others attempted to restrict the absolute sizes of RE projects (NG IT) (see also Fig. 3).

Tuscany adopted a coordinated approach between the regional and the provincial levels that identified both resource potential and the environmental implications of RE deployment (RC_T IT). Although Apulia lacked coordination among these different spatial levels, its forward-looking policy strategy led to the creation of a fast-track approval procedure and simplified licensing system that helped streamline the authorisation process for RE planning, project approval and installation. This catalysed 'a positive image' of the region and its policies, leading to increased interest from RE developers and investors attracted by lucrative national incentives and favourable natural resource conditions (DA IT). The Sardinian regional government sought to regulate energy-environmental planning for wind installations via the instrument of moratoriums. These moratoriums—de facto seeking to limit large-scale wind projects to protect the landscape—became the subject of long-term contestation and had the effect of delaying RE projects, ultimately discouraging investors.

Land-use planning and energy consenting have been critical in shaping RE deployment for both Scotland and Wales, offering much scope for autonomous policy development and influence over outcomes. In Wales, planning responsibility for energy is divided between the Welsh and UK governments depending on project size and onshore/offshore location. The Technical Advice Note 8: Planning for RE (TAN 8) represents the sphere in which

the regional government has done most to steer energy development within its territory (especially for onshore wind). TAN 8—a Welsh 'national zoning framework' [65: 175]—offered a potentially supportive policy context for wind power development, acting as a 'stabilising condition for investment' [65]. Nevertheless, wind deployment has been slower and patchier than in Scotland [92]. The spatial concentration of large-scale windfarm applications within the seven TAN 8 zones, coupled with the requirement for major new grid connections, triggered protests and subsequent refusal of planning consent despite the supportive spatial policy. This cast a shadow over the suitability of the zoning approach to yield the desired implementation targets for renewables (RB W). In contrast, planning is often seen as an ingredient in Scotland's relative success in delivering RE [65]. The Scottish Government played a key role in steering RE consent, by its policy of encouraging local planning authorities to adopt a favourable stance towards RE development and using its power of 'strategic plan approval' to overturn local authority zone definitions if these were considered too spatially restrictive.

These examples show some of the differences that occurred in organising the relationship between RE energy resources and the policy challenges that RE deployment has presented for the management of land-use. The regions considered have shown an increased governance capacity over energy and have made use of spatial planning policy and implementation to manage RE deployment. Regional governments have sought to organise the relationship between energy resource and land-use values and interests, reflecting the differing capacities and willingness of regional actors to render land available for RE development, variously constructing opportunities for, and barriers against, RE development.

The nature and content of discourses, narratives and visions for renewable energy deployment

As discussed, different actors can organise and mobilise specific resources, with the aid of, and in relation to, natural resource endowments, creating particular visions), development paths and policies, prioritising interests and mobilising resources for RE generation. In many cases, regions, although they may not control economic framework conditions (e.g. nationally set subsidies and feed-in tariffs), can promote coherent shared visions for the exploitation of their indigenous renewable resources [29, 52, 93]. Visions can often mobilise actors and resources, influencing which RE-related discourses gain hegemonic status and which are marginalised [94] and the extent to which the dominance of other energy sources can dilute or reinforce the power of emerging RE discourses [95]. Opposing and supporting discourses can also be framed differently at local and national levels via competing conceptualisations of the rural 'resource' [96].

The regions under investigation promoted RE deployment in various ways, through exploiting regional renewable resources for the benefit of their territory, identifying priorities that differed from those at national levels, and privileging specific RE sources over other energy sources (renewables and non-renewables). For example, RE development in Apulia was seen as an opportunity to alter patterns of economic growth. Breaking the trajectory of fossil fuel path dependence became a major goal of its regional energy policy, combined with the desire to support RE development rather than new nuclear capacity. The region's commitment to support the growing number of firms and research capabilities in the RE cluster sent strong directional signals. Most significant was how the Apulian government streamlined and accelerated the bureaucratic procedures of license concessions, promoting public sector deployment and financial support for the creation of RE parks.

The measures adopted for the diffusion of RE in Tuscany were primarily aimed at overcoming the lack of technology transfer processes from university to industry, processes that were much less present than elsewhere in Northern Europe and the US [97]. The regional energy plan promoted a new model and vision for Tuscany, the '*Modello Toscana Green*', based on an industrial strategy for RE aimed at stimulate networking and technology transfer activities between local research institutes and the small and medium firm base. Moreover, in Tuscany, the already greater deployment of RE resources, such as geothermal and hydro, influenced the choices made concerning RE deployment, with nationally set regional RE targets having been reached by these sources alone.

The peculiarities of Sardinia's energy system, devoid of natural gas resources or supply, with 94% energy dependence on mainland Italy, significantly influenced RE deployment narratives there. Two major infrastructure projects have de facto dominated RE and energy priorities: the construction of a large submarine power cable to connect Sardinia with Tuscany to overcome a condition of energy isolation [98]; and the opportunity offered by the construction of a gas pipeline connecting Algeria to the Italian mainland passing through Sardinia (the GALSI National Project). The latter was originally conceived as a win–win solution for region and nation. Although the project has currently come to a halt, the proposed gas pipeline was seen as an investment strategy that could guarantee the natural gas supply to the region and help the national government to deliver a more secure energy system.

Scotland and Wales have each produced energy strategies and policies that stress their own regional visions and

aspirations for RE development. In a context of declining oil and gas production, successive Scottish Governments have positioned RE expansion as central to Scotland's national economic future, with a sustained emphasis on green jobs, economic growth and international competitive advantage, and have advanced an ambitious strategy for the development and deployment of indigenous natural resources. Post-1998 Scottish independence debates[3] illustrate how the Scottish National Party, and its leadership, has regarded energy development—and RE—as part of the imagery of an independent Scotland [29, 99]. The vision(s) for RE deployment became part of a much stronger drive towards Scottish independence (e.g. to gain further control over energy policy). Significantly, this political vision of harnessing the comparative advantage of Scotland's natural resource potential benefitted from cross-party support that also opposed nuclear newbuild. A critical mass of actors (including major energy businesses, RE energy trade associations and regional development agencies) have also mobilised financial and other resources for project delivery, helping the Scottish Government to use its available powers assertively to facilitate project implementation.

Welsh governments have sought to 'act' on energy as an integral part of their wider economic and environmental agendas and policies, to 'maximise the potential for RE in Wales' and attract significant new investment, based on harnessing the region's natural resources. Nonetheless, the approach followed was, at first, considered as lacking clarity and focus in terms of RE policy delivery (e.g. ministerial responsibility for the energy portfolio has not been consistently clear and with limited ministerial drive in the face of public dissent with windfarm and associated infrastructure developments). These factors, to some extent, increased developers' scepticism around the Welsh Government leaders' capacity and willingness to demonstrate policy leadership on driving the RE agenda forward. It fed perceptions of a tentativeness about the likely realisation of the often grand 'visions' for RE deployment in Wales. Wales also lacked the industry presence and support that was evident in Scotland, and elite consensus has been more difficult to maintain [65]. Yet efforts to establish an enabling environment to proactively facilitate both onshore and offshore energy developments have increased in recent years, underpinning a renewed vision for a 'low-carbon future for Wales' [100].

Various targets and aspirations for increased levels of electricity production from RE at different scales have been set. Italy adopted a 'burden sharing' principle that 'distributed' the national target for RE between Italian regions following a detailed methodology [101]. However, as stated, the multi-year delays in this methodology's development left the regions seven years in which to decide on their own targets, indeed whether to set targets at all. In practice, regional targets for 2020 (before and after the burden-sharing) were exceeded in both Apulia and Sardinia by the intermediate period of 2016 while Tuscany achieved its burden-sharing targets in 2018.

In Scotland and Wales, on the contrary, target setting became a key feature, and a policy output of devolution, providing an important act of differentiation from Westminster [50]. Targets in the two devolved administrations were derived directly from regional growth agendas that reflected mainly 'domestic' processes, such as political agenda setting, assessment of the resources available and projects in the pipeline [50]. While Scotland managed to meet a succession of its own targets set above the UK norm, acting as a 'positive feedback loop' [102: 26], in 2012 Welsh ambitions for RE expansion were 'a wish list, rather than a concrete action plan for delivery' [103: 1992]. Nevertheless, both targets and a timeline for action were considered important to drive RE deployment in Wales (RA W) and following pressures from several actors in RE, new targets were re-instated in 2017 for energy generation in Wales from renewable sources.

Summarising, this section has explored how some regions have sought, via different discourses, narratives or visions, to promote and achieve a variety of policy strategies aimed at achieving both energy and non-energy objectives. Some have sought to capitalise on the opportunities offered by RE deployment to promote clustering activities and foster economic development and innovation within their territory; some have seen RE deployment as an opportunity to promote networking and knowledge transfer across many actors involved, while others have mobilised RE deployment as an opportunity to foster regional identity and independence. Different policy strategies, deployment rates and RE paths have been pursued to fulfil specific visions and trajectories; they show how specific RE sources can get selected over other energy sources (renewables and non-renewables), and illustrate how regional energy policy-making intersects significantly with a range of other policy areas and priorities.

The nature, extent, management and regulation of built infrastructure requirements for renewable energy delivery and the power to shape such infrastructure

The upgrading, management and regulation of transmission and distribution networks is critical for the successful integration of renewable power [104]. With the expansion of RE capacity, electricity network structures

[3] A referendum on Scottish independence took place on September 2014, to deliberate on Scottish independence from the UK, with 55% voting against the proposal.

and their management have increasingly become a strategic concern [41]. While the national level is important, most challenges surrounding energy infrastructure provision and governance simultaneously involve several spatial levels [7]. Managing grid capacity and infrastructure upgrades becomes a site-specific issue that implicates the region in policy strategies and actions to steer, facilitate or hold back infrastructure requirements, including planning processes and approvals [33, 41].

The rapid increase in RE penetration in Italy between 2010 and 2012, required changes both at transmission and distribution levels, ranging from dispatch operations (to increase system efficiency) to the introduction of mechanisms to enhance performance and measurement of frequency regulation and the construction of new lines [105]. However, congestion problems grew in Southern Italy. The overwhelming number of RE initiatives in Apulia resulted in negative effects on the national electricity system, increasing the pressure, at the regional level, to overcome the impact of the plants on the wider energy network (RG_A). Apulia's regional network capacity relies especially on 150 kV lines, which do not allow the dispatch of all the power produced. Moreover, small municipalities show high electricity reverse flows among the regional primary substations. Pending connection requests in Apulia by 2014 represented almost 50% of the entire national figure, nearly four times larger than those of other southern regions and much above the national average [106]. While Tuscany has been somewhat affected by infrastructural issues, against the two network investment interventions necessary in the north and in the centre of Italy, Apulia required 12, three of which were for new interregional interconnections, with the remaining nine concerning the development of 380 kV high-voltage collection stations.

Sardinia has an electricity grid with limited interconnection to the Italian mainland, a relatively small thermoelectric park and saw a reduced energy demand due to the economic downturn of recent years [107]. The network infrastructure also presents distinctive bottlenecks and limitations, including a weakly 'meshed' transmission and distribution line (with no meshing of the 380-kV network) which has caused line overloads and voltage problems [108]. These shortcomings have reduced the opportunities for connection and energy export, leading to a more severe control from the transmission operator and greater exposure to limiting dispatch orders [109]. These physical constraints continue to represent a limiting factor for RE deployment [110, 111] ('in Sardinia (..) the problem we have is that of the impact of renewables on the wider electricity network', RC S).

Although both Apulia and Sardinia have experienced higher levels of congestion due to the physical constraints of their respective local transmission and distribution networks, they also managed to establish relations with network operators to: (i) facilitate and speed up the consenting processes, and (ii) collaborate with network providers on the programming of electricity network infrastructure enhancement (via infrastructure governance round tables and Memoranda of Understanding). Infrastructure limitations have also created opportunities for Apulia and Sardinia to become key sites for the experimentation of innovative technologies and electrical infrastructure (e.g. electricity storage) (RC S; RG A).

The speed and extent of electricity network upgrading in the UK has been unsatisfactory and the national grid infrastructure was considered a cause of the main 'external failures' in the mid-2000s that delayed achievement of RE targets at that time [112]. Network developments and enhancements tended to follow a response-mode approach to new electricity generation. Moreover, a regulatory approach based on an 'invest then connect' principle, in vigour until 2009, led to an extensive queue of prospective new projects waiting for the completion of any necessary reinforcements to support their connection [113]. While regulatory changes since then have partially mitigated this problem, the increase in RE generation capacity caused many parts of the grid to become 'closed to new connections',[4] with congestion problems unevenly distributed across the UK.

Power from RE generation in the north of Scotland has increasingly flowed towards the south (Scotland and GB), adding to a network system that was already operating at its maximum capacity [114]. The Scottish Government's 2013 Electricity Generation Policy Statement [115] highlighted how Scotland expected to have an 'excess generation capacity that can be exported through existing and planned export links' [115: 35]. Hence, wider linkages have been needed for grid upgrades and reinforcements to enable electricity distribution from the north of Scotland energy sources to English demand centres. Improved interconnectors between Scotland to England, and the North and Irish Seas and intra-regional connections between the main islands of the Western Isles, Orkney and Shetland are planned to resolve such bottlenecks.

Both onshore and offshore wind generation connections in Wales, together with the potential connection of a new nuclear power station on the island of Anglesey, raised regional connection issues in North and mid-Wales [114]. The TAN 8 planning area in mid-Wales did not contain capacity for large-scale wind developments

[4] 'UK electricity grid holds back renewable energy, solar trade body warns', Farrell, S., 10th of May 2015, Guardian, https://www.theguardian.com/business/2015/may/10/uk-electricity-grid-renewable-energy-solar-trade-association.

[116] due to infrastructural constraints both at transmission and distribution levels. Plans for major new 400-kV grid lines were met with protests that ultimately halted further project developments in the area. The need for a flexible, affordable and 'smarter' grid infrastructure is considered a fundamental enabler to achieve a 'smarter energy future' for Wales [100].

Since UK electricity privatisation in 1990, key electricity decisions have been taken by arms-length regulators that operate on a UK-basis, and regulatory arrangements make it difficult to drive forward major system reinforcements. This creates challenges and delays and, at the regional level, can also frustrate policies for RE delivery (RB W). Hence, the Scottish Government has signalled consistently the importance of infrastructure renewal (NG S). The 2004 first National Planning Framework for Scotland already contained a section on energy infrastructure and subsequent versions followed suit [117]. The Scottish Government also showed support for the most significant grid reinforcement (the transmission line from Beauly to Denny). Beyond the immediate and practical management of the decision-making process, the Government signalled a clear commitment to the project, which sustained industry efforts towards RE generation during a heavily contested consenting process [118]. The Scottish Government has also been heavily involved in the negotiations around grid issues at a strategic level, engaging with the UK Government, Scottish Power Transmission and Scottish Hydro Electric Transmission plans, the National Grid, and OFGEM (the national energy regulator) on future network development and on the regulatory frameworks to deliver this. These relationships allowed for the fast-tracking of Scottish Power Transmission and Scottish Hydro Electric Transmission plans, including investment of £7 billion in Scotland's high-voltage transmission network by 2021. Recently the WG has also sought to strengthen the relationship with transmission and distribution network providers, working with UK Government to achieve clarity on devolution of consenting in relation to the grid through the Wales Bill[5] [100].

Steering and managing the electricity network, at the regional level, is clearly often problematic. Nevertheless, we have stressed how the regions under consideration have variously participated in, and supported, decision-making processes for infrastructure renewal, and we have identified the types of constraints and policy challenges the available infrastructure and its upgrading have posed in these regions.

[5] Following the Wales Bill (2016), the Welsh Government acquired direct central consenting powers on projects over 10 MW (from 2016) up to 350 MW (from 2017); previously none.

While the regional level has had a modest influence on the regulation of network infrastructure in the chosen cases, there are differences in how regions, and regional governments, have rendered their territory, directly or indirectly, available for infrastructural investment and in mediating potential constraints, both material/infrastructural and in terms of the power and influence that regional actors have had on infrastructure renewal. It can be argued that regional RE energy governance has been expressed predominantly via regional RE targets and RE strategies, suggesting that regional agency might lie in discretionary regional economic development spending [30]. However, some regions have had to participate in, and support, decision-making processes for infrastructure renewal to overcome the type of constraints and limits the infrastructure has posed in their regions. We return to this point in the next section.

Discussion

This section has two subsections. The first discusses the implications of the findings in relation to questions of institutions, governance and policy-making, and infrastructure; the second discusses how our analysis of how regional differences in RE deployment arise and operate in practice, yields policy-relevant insights.

Discussion 1: regional institutional settings, governance and policy-making, and infrastructure issues

The sections above have applied the framework of the three socio-material dimensions illustrated in Table 1 to identify key similarities and differences that emerged in the case studies and related them to policy strategies and choices and their implementation. This has enabled the analysis to show the many ways in which local and regional actors have engaged with RE and RE policy-making. We now turn to examine how these socio-materialities of RE provide a more nuanced view of the interplay between institutions, governance and policy-making, and infrastructure issues and how they have enabled or constrained RE transitions in the cases investigated (see Table 2).

The previous discussion shows that regional governments have sought to organise the relationship between energy resources, land-use values and interests by variously constructing opportunities for, and in some cases barriers against, RE development. Regions have had various responsibilities for regional energy plans, strategies and policies for the development and exploitation of endogenous renewable resources, and have used institutions such as spatial planning and vision(s) to promote or limit RE expansion. Spatial planning has been used for various purposes, for instance aiding and accelerating RE expansion (Apulia), to preserve the historical and

Table 2 Key features that influenced RE deployment in the regions investigated

Socio-material dimensions of RE	Institutions	Governance and policy-making	Infrastructure issues
Renewable energy sources as potentially deployable sources of energy that interact with current land-based resource use	*Spatial planning and land-use* *Facilitation of consenting processes* Apulia: XXX Wales Scotland Tuscany and Sardinia: X *Land ownership and availability (e.g. 'land reservoir')* Apulia and Scotland: XXX Wales Tuscany and Sardinia: X	*Regional agency and spatial planning* *Distribution of power in planning* Scotland: XXX Apulia, Tuscany and Sardinia: XX Wales (up to 2018?): X *Facilitating coordination at lower level* Scotland and Tuscany XXX Wales, Apulia and Sardinia: X	*Transmission and Distribution infrastructure renewal* *Current infrastructure endowments* Tuscany and Scotland: XX Wales, Apulia and Sardinia: X
The nature and content of discourses, narratives and visions for renewable energy deployment	*Shared visions and binding expectations* *Visions for RE* Apulia, Scotland XXX Wales: XX Tuscany and Sardinia: X *RE vis-à-vis alternative sources* Apulia, Scotland: XXX Tuscany: XX Wales and Sardinia: X	*Targets/aspiration settings and legitimisation* *Targets and resource availability as drivers for RE* Apulia and Scotland: XXX Wales: XX Tuscany and Sardinia: X *Political will for RE expansion and elite consensus* Apulia and Scotland: XXX Wales Tuscany and Sardinia: X	*Energy security and access* *How visions include grid capacity and renewal (limit/opportunities)* Tuscany XXX Apulia, Scotland XX Wales and Sardinia: X
The nature, extent, management, and regulation of built infrastructure requirements for RE delivery and the power to shape such infrastructure	*Regulations and standards* *Regulatory power over infrastructure* Apulia, Scotland Wales, Tuscany and Sardinia: X	*Regional agency and economic development* *Political will for RE expansion and elite consensus* Apulia and Scotland: XXX Wales Tuscany and Sardinia: X *Sites for experimentation* Apulia and Sardinia: XXX Scotland XX Wales: X	*Local infrastructure development* *Participation and involvement in infrastructure renewal* Apulia and Scotland: XXX Tuscany: XX Wales and Sardinia: X

The number of Xs represents the extent to which each feature was present and influenced RE deployment in each region, as derived from the case study research. For instance, one X denotes that although the feature is present, it has shown little impact on the deployment of RE, whereas three Xs (XXX) shows that this feature has played a leading role in influencing RE deployment in the region. Two Xs (XX) indicates that while the feature is significant, it is not a key driver of RE deployment

cultural characteristics of the territory (Tuscany), and to provide spatial selectivity (Wales). Moreover, the framing of RE deployment in the case studies shows that regional governments have mobilised different compelling visions to promote RE deployment, exploiting regional renewable resources for the benefit of their territory, identifying priorities that sometimes differ from and contrast with those set at national levels, and prioritising specific RE sources over other energy sources (renewables and non-renewables).

In terms of governance and policy-making, in two of the Italian regions RE targets were not seen as a specific instrument for driving RE deployment initiatives (Apulia was the exception), while, in contrast, they played an important role in both Scotland and Wales, becoming to a certain extent both a key feature and a policy output of devolution [50]. The discussion shows that the regional governance capacity to act for RE has been expressed predominantly via regional RE targets, RE strategies and spatial planning to promote RE deployment. To some extent, this reflects the fact that regional governments have had different powers to mediate the exploitation of RE, capitalising on regional assets and translating national objectives and targets into concrete agendas and policies for action that reflected regional specificities.

Moreover, the capacity of the regional level to influence the electricity transmission and distribution networks becomes especially important as RE uptake increases. In steering infrastructure renewal, the national level has played an important role and the regions investigated do not have the political legitimacy to govern grid regulation or the financial resources associated with it. Nevertheless, some of the cases investigated highlight how regional actors (and the presence in the territory of the transmission operator) allowed relationships to be established with those who own, operate and regulate the electricity network infrastructure, helping to shape infrastructure network renewal and reduce the constraints on RE deployment in their territory, as in the case of Scotland. In Apulia, regional actors played an active role as project partners and in the decision-making processes about regional infrastructure, allocating resources for infrastructure development in their regional economic planning by channelling European funding. In the island of Sardinia, on the contrary, physical and material constraints offered opportunities for the transmission

operator to solve structural issues in the region by adopting and testing innovative solutions.

The discussion above offers an account of how the socio-material dimensions of RE have influenced how regional actors engage with energy systems, flows and infrastructures in order to meet particular goals. The discussion stressed how the regions investigated have made use of targets, energy strategies/visions and spatial planning to promote RE deployment. Moreover, while the regional capability to act is often affected by the lack of legitimacy to govern and shape the electricity infrastructure networks as RE uptake increases [49], network infrastructures become an important mediating factor between physical resource endowments and institutional/governance structures at the regional level, and a key aspect of the ability of regional RE developments to supply electricity to meet national goals.

While the discussion points to how regions have set agendas via RE policy strategies and their implementation, the heuristic employed in the paper allows for a fine-grained analysis of the different influences the socio-material dimensions of RE can exert in terms of existing regional capabilities and agency, institutional dimensions and infrastructure.

We now turn the discussion to draw together the key policy-relevant insights from the analysis that offer food for thought for regions other than those we examined. The emphasis, in the discussion that follows is to point towards some useful lessons that can be learnt to inform what regional governments can achieve as the 'middle level' in a multi-level governance system.

Discussion 2: policy-relevant insights for regional renewable energy deployment

The importance of regional and sub-national governments in developing and implementing RE policies has been highlighted in the recent RE transitions literature [37, 45]. This recent work emphasises how actors can purposively seek to change the institutional settings to create space for RE and how a multi-level governance approach can highlight instances where regions and sub-national governments have exercised wider authority and autonomy in order to increase RE uptake. Undoubtedly, the growing priority of accelerating progress towards net-zero greenhouse gas emissions [2] has renewed emphasis on the need to increase the development of RE. While critical questions remain as to how to speed up RE deployment, the approach used in this paper highlights how policy-makers need to be more effective in balancing the range of goals/interests for RE deployment with the peculiarities and specificities of their regional socio-material contexts. As we have shown, with the aid of the framework depicted in Table 1, these have influenced RE uptake in the regions investigated, and have wider implications for policy-makers and policy thinking.

Firstly, a 'one-size fits all' nationally determined solution that disregards local and regional specificities might have a detrimental effect on RE deployment; it is likely to cause frictions at local and regional levels, including problematic public acceptance of projects, and act as a barrier to development. This is particularly evident in the way in which regional governments in the regions investigated have mobilised spatial planning to promote RE deployment. This process was influenced by the specific regional contexts in which RE projects emerged (e.g. land availability and the cultural and historical characteristics of each region). The degree of political autonomy in planning, the capacity to facilitate consenting processes at sub-regional levels, and the way in which land preferences acted as 'reservoirs of land', contributed in some regions (e.g. Apulia and Scotland) to increases in the uptake of RE. This is increasingly relevant as the prices of electricity from RE such as wind and solar become competitive without state subsidy, and where questions about siting may become the pre-eminent challenge in RE expansion—especially so as developers seek scale efficiencies through larger projects. There is a need for regional energy strategies and policies to be closely aligned with land-use planning processes and institutions, and to facilitate decision-making by explicitly, clearly and justly balancing trade-offs between multiple energy and non-energy objectives and managing conflict.

Secondly, the socio-material dimensions of RE also emphasise the range of agencies that may be involved in establishing, contesting and reproducing expectations and visions as RE deployment unfolds. The roles of different types of actors and how they organise interests and priorities for RE deployment matter. These roles, the coalitions they assemble to promote or restrain renewable deployment, and the different interests involved in the framing of RE strategies are crucial. For instance, Scotland's relative success in the UK builds on a strong actor-network coalition involving a range of organisations. Engaging with a wider group of actors and interests can facilitate access to finance and resources for project delivery and, by the process of 'joining forces', helps to build a supportive and credible environment for RE promotion. Hence, factors such as the degree of heterogeneity of the actor-sets, the level of coordination between them, and the interests/objectives that connect them can exert significant influence. The devices used for consultation, experimentation and consensus building become highly important. Hence, there is a role for policy-making in creating spaces for current and new actors to engage in the identification and promotion of visions

for RE deployment and to align these visions with plans for action.

While visions can be framed differently depending on local/regional specificities, their policy relevance can be expressed in two ways. On the one hand, regional policy-makers are often faced with a choice around competing regional visions and expectations that intersect variously with non-energy policy objectives. A process of negotiation around priorities is required to enrol the engagement of different actors in the kinds of broad consensus that emerged in Scotland and Apulia. This process can involve a multi-dimensional contest over the relative potency and authority of different vision(s) and their significance for driving RE deployment and achieving wider objectives. For example, can a champion narrative be identified to convey and translate local/regional relevance and is there the political will to pursue it, often in the face of dissent? Moreover, if they are to offer a convincing path forward, the vision(s) promoted need to be nurtured by credible expectations, building from past development (and success) and the actual level of performance. The research has shown that as well as lack of clarity or the 'tentativeness' of regional visions, regulatory and policy uncertainty and delay, at national and regional levels, can act as institutional and administrative barriers. These are important policy considerations for the effective deployment of RE.

Thirdly, the examples illustrate that regional political commitment has often been able to overcome lack of formal power, for example by facilitating RE deployment via coordination and the establishment of relationships with network operators (e.g. in Apulia and Scotland) and local authorities/provinces (e.g. in Tuscany to limit large-scale RE deployment). Therefore, a strong engagement in formal and informal networks at different spatial levels can significantly aid RE deployment processes. Such engagements can be effective not only in enabling an extensive exchange of expertise [119], but also in influencing outcomes (e.g. facilitating consenting processes, enhancing infrastructure, and allowing regions to become sites of experimentation with innovative technologies), as in Apulia and Sardinia. Moreover, infrastructures that deliver energy from regional source to national users may or may not benefit regional communities along the way. History suggests that regional policy-makers would be wise to ensure that renewable electricity delivery systems deliver local benefits and design them in ways that spread the costs and benefits in as fair a manner as possible [120].

We have shown that institutional capacity and governance, how varied actors organise interests and priorities for RE deployment, spatial planning, compelling visions and credible expectations are all necessary prerequisites for coherent policy outcomes. Their effects, and how they combine in practice, will be influenced and contoured by specific regional contexts: each will have their own particular environments, resource endowments, infrastructure, demographic, socio-economic and governance structures. These insights are useful to explain how energy policy strategies, choices and outcomes can be shaped in particular places, how these differences can arise and operate in practice, and need to be taken into account in policy design and implementation at both national and regional scales.

Conclusion

Through comparative case study analysis, this paper set out to find insights for policy thinking, policy-making and policy implementation by exploring the influence exerted by the interacting socio-material dimensions of RE on energy infrastructure and its governance, outlining how these manifestations structure the ways in which local and regional actors engage with energy systems, flows and infrastructures to meet their goals. The paper argues that examining the socio-materialities of RE enables a fine-tuned analysis of how institutions, governance and policy-making, and infrastructure can enable or constrain energy transitions and policy effectiveness at local and regional levels. It employed a heuristic framework aimed at capturing the relationships that emerge in the interplay between the socio-material dimensions of RE and the three institutional, governance and infrastructure factors at the regional level. By doing so, the paper has highlighted the institutions that matter for RE and the varied effects that they can exert on regional RE deployment; and it has emphasised the range of agencies that may be involved in strategically establishing, contesting and reproducing institutions, expectations, visions and infrastructure as RE deployment unfolds at the regional level. Additionally, the paper has explored the nature and extent of infrastructure requirements for and constraints on RE delivery and how they affect the regional capacity to shape infrastructure networks and facilitate RE deployment.

The discussion has shown how the regions investigated variously developed their institutional, governance and policy-making capacities over energy and made use of targets, energy strategies/visions and spatial planning to promote RE deployment. Although the regional capability to act is often constrained by the lack of authority to govern the electricity infrastructure networks as RE uptake increases, several mediating factors emerged from examining the interactions between regional physical resource endowments and energy infrastructure renewal. We contend that the heuristic illustrated in Table 1 is useful for the analysis of RE deployment processes and

their spatial unevenness at the regional scale, contributing to research that highlights the role of institutional variations and governance as foundations for geographical differences in the adoption of RE that carry significant implications for policy thinking and implementation.

Appendix 1: List of organisations with which interviewees were associated

Ministero per l'Innovazione e lo Sviluppo Economico (MISE) (NG IT).
ENEL Green Power (Enel Group subsidiary for renewable sources) (RB IT).
Graziella Green, Renewable Energy Electricity producer (RB IT).
ENEA, National agency for new technologies energy and sustainable economic development (RC IT).
CNR (National Research Council) institute of geosciences and earth resources (RC IT).
ENEL Research Centre (Global Generation Division) (RC IT).
Horizon 2020 Representative for Italy in the area of Secure, Clean and Efficient Energy (UR IT).
TERNA, Italian Transmission Operator (NO IT).
Regione Toscana (Regional Government) (RG T).
DTE Toscana (technological districts for Energy Toscana Region) (DA T).
Magma Energy Italy, geothermal (RB IT).
40 South Energy, marine/wave energy (RB IT).
CRIBE, Research Centre for Biomass energy, Pisa University, Department of Civil and Industrial engineering (UR T).
Scuola Superiore Sant Anna, Innovation and Renewable Energy Research Group (UR T).
Regione Sardegna (Regional Government) (RG S).
Confindustria Nord Sardegna, Manufacturing and services association (BA S).
Elianto, Renewable Energy Electricity Producer (RB IT).
Sardegna Ricerche, Cluster Renewable Energy (RC S).
ARTI, Agenzia regionale per la tecnologia e l'innovazione (Apulia Development Agency) (DA A).
Regione Puglia- Regional Government (RG A).
Vestas, Wind Energy- Manufacturer (RB IT).
Tara Renewable Energy, Energy efficiency and smart buildings (RB IT).
CREA, Centro Ricerche Energia e Ambiente, Lecce University (UR A).
Foggia University, Economics Department (UR A).
Department of Energy and Climate Change (NG UK).
Welsh Government (RG W).
Natural Resources Wales (EA W).
Cardiff Council (LG W).
Tidal Energy ltd (RB W).
Pembrokeshire Marine Energy (RB W).
Tidal Power Lagoon (Swansea Bay Lagoon) (RB W).
RWE Innogy (Wales) Wind Energy (RB W).
Renewable UK Cymru (RA W).
Swansea University Marine Energy Group (RC W).
Scottish Government (RG S).

Abbreviation
RE: Renewable energy.

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Authors' contributions
CDL and PJGP have made substantial contributions to the design of the paper. CDL conceived the analytical framework, and was responsible for the acquisition, analysis and interpretation of data. Both authors have drafted the work or substantively revised it. They both approved the submitted version (and any substantially modified version that involves the authors' contribution to the study). They both agreed to be personally accountable for their own contributions. Both authors read and approved the final manuscript.

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Availability of data and materials
As described in the section on methods, the data used for the study were collected from many different sources. Documents consulted are publicly available and were referred to in text. The data collected during the interviews are confidential.

Declarations

Ethical approval and consent to participate
The research conducted during this study was approved by the Ethics committee of the Welsh School of Architecture of Cardiff University, reference n. EC 1504.231. All research participants signed consent to participate.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Cardiff School of Management, Cardiff Metropolitan University, Llandaff Campus, Western Avenue, Cardiff CF5 2YB, UK. [2]Welsh School of Architecture, Cardiff University and Centre for Environmental Policy, Imperial College London, Weeks Building, South Kensington, London SW7 1NE, UK.

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References

1. IRENA (2020) Renewables 2020 global status report. REN21 Secretariat, Paris
2. IPCC (2019) Global warming of 1.5°C: summary for policymakers (revised version). Intergovernmental Panel on Climate Change, Switzerland
3. Foxon TJ (2011) A coevolutionary framework for analysing a transition to a sustainable low carbon economy. Ecol Econ 70(12):2258–2267
4. Trencher G, Rinscheid A, Duygan M, Truong N, Asuka J (2020) Revisiting carbon lock-in in energy systems: explaining the perpetuation of coal power in Japan. Energy Res Soc Sci 69:101770
5. Seto KC, Davis SJ, Mitchell RB, Stokes EC, Unruh G, Ürge-Vorsatz D (2016) Carbon lock-in: types, causes, and policy implications. Annu Rev Environ Resour 41(1):425–452
6. Cherp A, Vinichenko V, Jewell J, Brutschin E, Sovacool B (2018) Integrating techno-economic, socio-technical and political perspectives on national energy transitions: a meta-theoretical framework. Energy Res Soc Sci 37:175–190
7. Goldthau A (2014) Rethinking the governance of energy infrastructure: scale, decentralization and polycentrism. Energy Res Soc Sci 1:134–140
8. Bridge G, Gailing L (2020) New energy spaces: towards a geographical political economy of energy transition. Environ Plann A Econ Space 52(6):1037–1050
9. Meadowcroft J (2016) Let's get this transition moving! Can Public Policy 42(S1):S10–S17
10. Castán Broto V, Baker L (2018) Spatial adventures in energy studies: an introduction to the special issue. Energy Res Soc Sci 36:1–10
11. Becker S, Moss T, Naumann M (2016) The importance of space: towards a socio-material and political geography of energy transitions. In: Gailing L, Moss T (eds) Conceptualizing Germany's energy transition: power, materiality and space. Palgrave Pivot, London, pp 93–108
12. Gailing L, Moss T (eds) (2016) Conceptualizing Germany's energy transition institutions, materiality, power, space. Palgrave Macmillan UK, London
13. Calvert K (2015) From 'energy geography' to 'energy geographies.' Prog Hum Geogr 40(1):105–125
14. Labussière O, Nadaï A (eds) (2018) Energy transitions a socio-technical Inquiry. Palgrave Macmillan, Gewerbestrasse
15. Gailing L, Röhring A (2016) Is it all about collaborative governance? Alternative ways of understanding the success of energy regions. Utilities Policy 41:237–245
16. De Laurentis C, Pearson PJG (2018) Understanding the material dimensions of the uneven deployment of renewable energy in two Italian regions. Energy Res Soc Sci 36:106–119
17. Castán Broto V (2019) Urban energy landscapes. Cambridge University Press, Cambridge
18. Kuzemko C, Lockwood M, Mitchell C, Hoggett R (2016) Governing for sustainable energy system change: politics, contexts and contingency. Energy Res Soc Sci 12:96–105
19. Bridge G, Özkaynak B, Turhan E (2018) Energy infrastructure and the fate of the nation: introduction to special issue. Energy Res Soc Sci 41(1):1–11
20. Binz C, Coenen L, Murphy JT, Truffer B (2020) Geographies of transition—from topical concerns to theoretical engagement: A comment on the transitions research agenda. Environ Innov Soc Trans 34:1–3
21. Köhler J, Geels FW, Kern F, Markard J, Onsongo E, Wieczorek A, Alkemade F, Avelino F, Bergek A, Boons F et al (2019) An agenda for sustainability transitions research: state of the art and future directions. Environ Innov Soc Trans 31:1–32
22. Chlebna C, Mattes J (2020) The fragility of regional energy transitions. Environ Innov Soc Trans 37:66–78
23. Mattes J, Huber A, Koehrsen J (2015) Energy transitions in small-scale regions—what we can learn from a regional innovation systems perspective. Energy Policy 78:255–264
24. Hansen T, Coenen L (2015) The geography of sustainability transitions: review, synthesis and reflections on an emergent research field. Environ Innov Soc Trans 17:92–109
25. De Laurentis C (2013) Innovation and policy for bioenergy in the UK: a co-evolutionary perspective. Reg Stud. https://doi.org/10.1080/00343404.2013.834320
26. Gibbs D (2018) Sustainable regions. In: Paasi A, Harrison J, Jones M (eds) Handbook on the geographies of regions and territories. Edward Elagr Publishing Ltd, Cheltenham, pp 182–194
27. Trippl M, Baumgartinger-Seiringer S, Frangenheim A, Isaksen A, Rypestøl JO (2020) Unravelling green regional industrial path development: regional preconditions, asset modification and agency. Geoforum 111:189–197
28. Njøs R, Sjøtun SG, Jakobsen S-E, Fløysand A (2020) Expanding analyses of path creation: interconnections between territory and technology. Econ Geogr 96(3):266–288
29. Dawley S, MacKinnon D, Cumbers A, Pike A (2015) Policy activism and regional path creation: the promotion of offshore wind in North East England and Scotland. Camb J Reg Econ Soc 8(2):257–272
30. MacKinnon D, Dawley S, Pike A, Cumbers A (2019) Rethinking path creation: a geographical political economy approach. Econ Geogr 95(2):113–135
31. Fuchs G, Hinderer N (2014) Situative governance and energy transitions in a spatial context: case studies from Germany. Energy Sustain Soc 4(1):16
32. Fornahl D, Hassink R, Klaerding C, Mossig I, Schröder H (2012) From the old path of shipbuilding onto the new path of offshore wind energy? The case of Northern Germany. Eur Plan Stud 20(5):835–855
33. Balta-Ozkan N, Watson T, Mocca E (2015) Spatially uneven development and low carbon transitions: insights from urban and regional planning. Energy Policy 85(Supplement C):500–510
34. Grillitsch M, Hansen T (2019) Green industry development in different types of regions. Eur Plan Stud 27(11):2163–2183
35. MacKinnon D, Dawley S, Steen M, Menzel M-P, Karlsen A, Sommer P, Hansen GH, Normann HE (2019) Path creation, global production networks and regional development: a comparative international analysis of the offshore wind sector. Prog Plan 130:1–32
36. De Laurentis C (2021) What are the regionally specific institutions that matter for renewable energy deployment and how can they be identified? Some insights from Italian regions. Local Environ. https://doi.org/10.1080/13549839.2021.1904859
37. Bradshaw A, de Martino JG (2019) Governing energy transitions and regional economic development: evidence from three Brazilian states. Energy Policy 126:1–11
38. North D (1990) Institutions, institutional change and economic performance. Cambridge University Press, Cambridge
39. Bridge G, Özkaynak B, Turhan E (2018) Energy infrastructure and the fate of the nation: Introduction to special issue. Energy Res Soc Sci 41:1–11
40. Ćetković S, Buzogány A (2016) Varieties of capitalism and clean energy transitions in the European Union: When renewable energy hits different economic logics. Clim Policy 16(5):642–657
41. Sataøen HL, Brekke OA, Batel S, Albrecht M (2015) Towards a sustainable grid development regime? A comparison of British, Norwegian, and Swedish grid development. Energy Res Soc Sci 9:178–187
42. Cotton M, Devine-Wright P (2013) Putting pylons into place: a UK case study of public perspectives on the impacts of high voltage overhead transmission lines. J Environ Plann Manag 56(8):1225–1245
43. Moss T, Becker S, Naumann M (2015) Whose energy transition is it, anyway? Organisation and ownership of the Energiewende in villages, cities and regions. Local Environ 20(12):1547–1563
44. Wirth S (2014) Communities matter: institutional preconditions for community renewable energy. Energy Policy 70:236–246
45. Jehling M, Hitzeroth M, Brueckner M (2019) Applying institutional theory to the analysis of energy transitions: from local agency to multi-scale configurations in Australia and Germany. Energy Res Soc Sci 53:110–120
46. Gibbs D, Jonas AEG (2000) Governance and regulation in local environmental policy: the utility of a regime approach. Geoforum 31(3):299–313
47. Morgan K (2004) Sustainable regions: governance, innovation and scale. Eur Plan Stud 12(6):871–889

48. While A, Jonas AEG, Gibbs D (2010) From sustainable development to carbon control: eco-state restructuring and the politics of urban and regional development. Trans Inst Br Geogr 35(1):76–93
49. De Laurentis C (2020) Mediating the form and direction of regional sustainable development: the role of the state in renewable energy deployment in selected regions. Eur Urban Reg Stud 0969776420904989
50. Cowell R, Ellis G, Sherry-Brennan F, Strachan PA, Toke D (2015) Rescaling the governance of renewable energy: lessons from the UK devolution experience. J Environ Policy Plann. https://doi.org/10.1080/1523908X.2015.1008437
51. Dawley S (2014) Creating new paths? Offshore wind, policy activism, and peripheral region development. Econ Geogr 90(1):91–112
52. Späth P, Rohracher H (2010) 'Energy regions': the transformative power of regional discourses on socio-technical futures. Res Policy 39(4):449–458
53. Hoppe T, Miedema M (2020) A governance approach to regional energy transition: meaning, conceptualization and practice. Sustainability 12(3):915
54. Rutherford J, Jaglin S (2015) Introduction to the special issue—urban energy governance: local actions, capacities and politics. Energy Policy 78:173–178
55. Roelich K, Bale CSE, Turner B, Neall R (2018) Institutional pathways to municipal energy companies in the UK: Realising co-benefits to mitigate climate change in cities. J Clean Prod 182:727–736
56. Gailing L, Bues A, Kern K, Röhring A (2020) Socio-spatial dimensions in energy transitions: applying the TPSN framework to case studies in Germany. Environ Plann A Econ Space 52(6):1112–1130
57. Bulkeley H, Castán Broto V, Maassen A (2013) Low-carbon transitions and the reconfiguration of urban infrastructure. Urban Stud 51(7):1471–1486
58. Rutherford J, Coutard O (2014) Urban energy transitions: places, processes and politics of socio-technical change. Urban Stud 51(7):1353–1377
59. Graham S, Marvin S (2001) Splintering urbanism: networked infrastructures, technological mobilities and the urban condition. Routledge, New York
60. Lawhon M, Nilsson D, Silver J, Ernstson H, Lwasa S (2017) Thinking through heterogeneous infrastructure configurations. Urban Stud 55(4):720–732
61. Svensson O (2021) The matter of energy emerges: bridging the divide between conflicting conceptions of energy resources. Energy Res Soc Sci 72:101895
62. Kuzemko C, Britton J (2020) Policy, politics and materiality across scales: a framework for understanding local government sustainable energy capacity applied in England. Energy Res Soc Sci 62:101367
63. Karvonen A, Guy S (2018) Urban energy landscapes and the rise of heat networks in the United Kingdom. J Urban Technol 25(4):19–38
64. Fontaine A (2020) Debating the sustainability of solar energy: examining resource construction processes for local photovoltaic projects in France. Energy Res Soc Sci 69:101725
65. Cowell R, Ellis G, Sherry-Brennan F, Strachan PA, Toke D (2017) Energy transitions, sub-national government and regime flexibility: how has devolution in the United Kingdom affected renewable energy development? Energy Res Soc Sci 23:169–181
66. Power ER, Mee KJ (2020) Housing: an infrastructure of care. Hous Stud 35(3):484–505
67. Gertler MS (2004) Manufacturing culture: the institutional geography of industrial practice. Oxford University Press, Oxford
68. Funcke S, Bauknecht D (2016) Typology of centralised and decentralised visions for electricity infrastructure. Util Policy 40:67–74
69. Hancock KJ, Palestini S, Szulecki K (2021) The politics of energy regionalism. In: Hancock KJ, Allison JET (eds) The Oxford handbook of energy politics
70. Newell D, Sandström A, Söderholm P (2017) Network management and renewable energy development: an analytical framework with empirical illustrations. Energy Res Soc Sci 23:199–210
71. Wolsink M (2017) Co-production in distributed generation: renewable energy and creating space for fitting infrastructure within landscapes. Landsc Res. https://doi.org/10.1080/01426397.2017.1358360
72. Lintz G, Leibenath M (2020) The politics of energy landscapes: the influence of local anti-wind initiatives on state policies in Saxony, Germany. Energy Sustain Soc 10(1):5
73. Nadaï A, Labussière O (2012) Le paysage éolien, décentralisation énergétique et paysagère. In: Bouneau C, Varaschin D, Laborie L, Viguié R, Bouvier Y (eds) Paysages de l'électricité. Peter Lang, Bruxelles, pp 185–202
74. Berkhout F (2006) Normative expectations in systems innovation. Technol Anal Strat Manag 18(3–4):299–311
75. Longhurst N, Chilvers J (2019) Mapping diverse visions of energy transitions: co-producing sociotechnical imaginaries. Sustain Sci 14(4):973–990
76. IEA (2020) Global energy review 2020. IEA, Paris
77. Yin RK (2014) Case study research design and methods, 5th edn. Sage Publications, Thousand Oaks
78. Wirth S, Markard J, Truffer B, Rohracher H (2013) Informal institutions matter: professional culture and the development of biogas technology. Environ Innov Soc Trans 8:20–41
79. Farole T, Rodriguez-Pose A, Storper M (2011) Human geography and the institutions that underlie economic growth. Prog Hum Geogr 35(1):58–80
80. Peck J (2003) Fuzzy old world: a response to Markusen. Reg Stud 37(6–7):729–740
81. Peck J (2015) Cities beyond compare? Reg Stud 49(1):160–182
82. Sovacool BK (2014) What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. Energy Res Soc Sci 1:1–29
83. Piovani JI, Krawczyk N (2017) Los Estudios Comparativos: algunas notas históricas, epistemológicas y metodológicas (Comparative studies: historical, epistemological and methodological notes). Educação Realidade 42:821–840
84. Nijman J (2015) The theoretical imperative of comparative urbanism: a commentary on 'cities beyond compare?' by Jamie Peck. Reg Stud 49(1):183–186
85. Hall P, Soskice D (2001) An introduction to varieties of capitalism. In: Hall P, Soskice D (eds) Varieties of capitalism: the institutional foundations of comparative advantage. Oxford University Press, Oxford
86. Dahlmann F, Kolk A, Lindeque J (2017) Emerging energy geographies: scaling and spatial divergence in European electricity generation capacity. Eur Urban Reg Stud 24(4):381–404
87. GSE (2018) Rapporto Statistico 2018 Impianti a fonti rinnovabili, Settore Elettrico. In: Gestore Servizi Energetici (ed) GSE, Rome
88. BEIS (2018) Energy trends. Department for Business, Energy & Industrial Strategy, London
89. BEIS (2015) Energy trends. Department for Business, Energy & Industrial Strategy, London
90. GSE (2016) Monitoraggio statistico degli obiettivi nazionali e regionali sulle fonti rinnovabili di energia, Anni 2012–2014. In: Gestore Servizi Energetici (ed) GSE, Roma
91. BEIS (2014) Regional renewable statistics regional statistics 2003–2016: installed capacity. Department for Business, Energy & Industrial Strategy, London
92. Ellis G, Cowell R, Sherry-Brennan F, Strachan P, Toke D (2013) Planning, energy and devolution in the UK. Town Plan Rev 84(3):397–409
93. Essletzbichler J (2012) Renewable energy technology and path creation: a multi-scalar approach to energy transition in the UK. Eur Plan Stud 20(5):791–816
94. Lupp G, Steinhäußer R, Starick A, Gies M, Bastian O, Albrecht J (2014) Forcing Germany's renewable energy targets by increased energy crop production: a challenge for regulation to secure sustainable land use practices. Land Use Policy 36:296–306
95. Szarka J (2007) Why is there no wind rush in France? Eur Environ 17(5):321–333
96. Lennon M, Scott M (2017) Opportunity or threat: dissecting tensions in a post-carbon rural transition. Sociol Rural 57(1):87–109
97. Di Minin A, Lazzeroni M, Piccaluga A (2006) Economic growth in knowledge intensive emerging areas: the high-tech cluster in Pisa. In: Cooke P, Piccaluga A (eds) Regional development in the knowledge economy. Routledge, Oxford, pp 183–202
98. Corsale A, Sistu G (2016) Surrounded by water: landscapes, seascapes and cityscapes of Sardinia. Cambridge Scholars Publishing

99. Toke D, Sherry-Brennan F, Cowell R, Ellis G, Strachan P (2013) Scotland, renewable energy and the independence debate: will head or heart rule the roost? Polit Q 84(1):61–70
100. Griffiths L (2019) Written response by the Welsh Government to the report of the environment and sustainability committee entitled a smarter energy future for Wales. In: Welsh Government (ed) Cardiff, Welsh Government
101. MISE (2010) Piano di azione nazionale per le energie rinnovabili (direttiva 2009/28/CE). In: Economico MdS (ed). Rome: Ministero dello Sviluppo Economico, pp 1–210.
102. WWF (2014) Scotland: a renewable power house. WWF Scotland, Dunkeld
103. De Laurentis C (2012) Renewable energy innovation and governance in Wales: a regional innovation system approach. Eur Plan Stud 20(12):1975–1996
104. Tenggren S, Wangel J, Nilsson M, Nykvist B (2016) Transmission transitions: barriers, drivers, and institutional governance implications of Nordic transmission grid development. Energy Res Soc Sci 19:148–157
105. IEA (2016) Energy policies of IEA countries—Italy 2016 review. In: IEA (ed). Paris: International Energy Agency
106. BURP: Bollettino Ufficiale Regione Puglia n. 51 del 15/04/2014 'Analisi di Scenario della produzione di energia e fonti energetiche rinnovabili sul territorio regionale. Criticita' di sistema e iniziative conseguenti. In. Bari: Regione Puglia; 2014
107. Terna (2017) Piano di sviluppo della Rete Elettrica Nazionale 2017. Terna S.p.A.-Rete Elettrica Nazionale, Roma
108. Purvins A, Wilkening H, Fulli G, Tzimas E, Celli G, Mocci S, Pilo F, Tedde S (2011) A European supergrid for renewable energy: local impacts and far-reaching challenges. J Clean Prod 19(17):1909–1916
109. RSE (2011) Energia eolica e sviluppo locale Territori, green economy e processi partecipativi. Ricerca Sistema Energetico-RSE SpA, Rome, pp 1–173
110. Regione Sardegna (2012) Piano energetico ambientale regionale al 2020, Rapporto preliminare di scoping. Regione Autonoma della Sardegna, Cagliari, pp 1–26
111. Benini M, Cirio D, Gatti A, Pitto A, Gelmini A, Brignoli V (2011) Espansione della fonte eolica e sicurezza del sistema elettrico: il caso della Sardegna al 2020, vol. 6 Vol. 88
112. Wood G, Dow S (2011) What lessons have been learned in reforming the renewables obligation? An analysis of internal and external failures in UK renewable energy policy. Energy Policy 39(5):2228–2244
113. IEA (2012) Energy policies of IEA countries—The United Kingdom 2012 review. International Energy Agency, Paris
114. ENSG (2012) Our electricity transmission network: a vision for 2020 a summary of an updated report to the electricity networks strategy group. Electricity Networks Strategy Group, London
115. SG, (2013) Electricity generation policy statement. Scottish Government, Edinburgh
116. Ove ARUP (2010) Research: strategic search area (SSA) reassessment and validation. Ove Arup and Partners, Cardiff
117. Ritchie H, Hardy M, Lloyd MG, McGreal S (2013) Big pylons: mixed signals for transmission. Spatial planning for energy distribution. Energy Policy 63(3):311–320
118. Cowell R, Ellis G, Sherry-Brennan F, Strachan PA, Toke D (2013) Promoting renewable energy in the UK what difference has devolution made? Cardiff University, Cardiff
119. Lutz LM, Fischer L-B, Newig J, Lang DJ (2017) Driving factors for the regional implementation of renewable energy—a multiple case study on the German energy transition. Energy Policy 105:136–147
120. Jones CF (2018) The materiality of energy. Can J Hist 53(3):378–394

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