Policy insights for regional renewable energy deployment

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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 the socio-materialities of renewable energy enable 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. The paper highlights that several mediating factors emerge from examining the interactions between regional physical resource endowments and energy infrastructure renewal. The analysis leads to several policy-relevant insights into what makes for renewable energy deployment.

Conclusion The paper contributes to research that highlights 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. The insights presented are useful 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 and implementation.

1.0 Introduction

The development, application and proliferation of renewable energy (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 (IRENA, 2020; IPCC, 2019). Because such transitions work against incumbent, widely locked-in fossil fuels and associated technologies, institutions, markets, cultural meanings and user practices, replacing fossil fuels with low-carbon alternatives implies a prominent role for policy and policy makers (Foxon, 2011; Trencher et al., 2020; Seto et al., 2016). While some of the most significant decisions to steer energy systems are made at the national level (Cherp et al., 2018), 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 (Goldthau, 2014). Besides, current configurations of energy flows have deep historical roots and are closely entwined with the overall development trajectory of territories (Meadowcroft, 2016). This history, and associated lock-in and path dependence, mean that efforts to accelerate the sustainable transition to greener energy systems need to start from a clear appreciation of these particularities (ibid.).

There is 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 is maturing (Binz et al., 2020; Köhler et al., 2019) a number of contributions emphasise the role that local and regional institutional settings play in influencing the pace and scope of sustainability transitions (Chlebna and Mattes, 2020; Mattes et al., 2015; Hansen and Coenen, 2015; De Laurentis, 2013). Similarly, a substantial body of literature has focussed on innovation and local/regional capabilities for developing new growth paths (Gibbs, 2018; Trippl et al., 2020), where regions emerge as sites for innovation and experimentation (Njøs et al., 2020; Dawley et al., 2015; MacKinnon et al., 2019a; Fuchs and Hinderer, 2014) and where objectives other than climate change, such as employment, may be achieved (Balta-Ozkan et al., 2015). Regional industrial specialisations, natural resource endowments and local/ regional institutional set-ups become therefore relevant. Hence, they promote differences in approaches to and outcomes of energy transitions and the policies that affect them (Grillitsch and Hansen, 2019; MacKinnon et al., 2019b).

Furthermore, within local and regional contexts, reconfigured or new organisations have been emerging to promote RE, but also to enhance sub-national control over energy policy (Moss et al., 2015; Kuzemko and Britton, 2020). While developing specific analytical and empirical preferences, these approaches emphasise how the varied combinations of assets- human, institutional, industrial, infrastructural and material- have shaped regional energy transitions in many ways. Hence similar regulatory settings (e.g. subsidies and incentives) can work in different ways at regional and local levels (De Laurentis, forthcoming) and local and regional development governance, visions and policies have an important role to play in supporting energy regional transitions (Bradshaw and de Martino Jannuzzi, 2019).

This paper adds to these contributions by further investigating this last point. It sets out to explore the ways in which regional[1] actors engage with energy systems, flows and infrastructures in order to meet particular goals. It does so, by stressing the influence that socio-material forms of energy exert on energy institutions, infrastructure and its governance (De Laurentis and Pearson, 2018; Kuzemko et al., 2016; Bridge et al., 2018). 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 areas and 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.

The comparative cases are three regions in Italy and two of the devolved territories of the UK, Wales and Scotland. 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 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 a variation of a coordinated market economy (Italy) (Hall and Soskice, 2001). These differences have affected energy policy preferences and influenced RE policies, shaping the adoption of RE technologies (Dahlmann et al., 2017; Ćetković and Buzogány, 2016; Kuzemko et al., 2016).

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

2.0 Renewable Energy Socio-materialities And Their Relations With Institutions, Governance And Infrastructure

Focusing on RE deployment at the regional level, this paper contends that that these deployment processes and their spatial unevenness and their susceptibility to particular policies can be better understood by taking more account of the influence exerted by the socio-material manifestations of energy on energy infrastructure and its governance (De Laurentis and Pearson, 2018; Bridge et al., 2018; Kuzemko et al., 2016). This is because they structure the ways in which local and regional actors engage with energy systems, flows and infrastructures to meet their goals. What follows briefly reviews the recent socio-material turn and proceeds by discussing how the socio-materialities of RE enable a more fine-tuned analysis of how institutions, governance and infrastructure can enable or constrain energy transitions at local and regional levels.

2.1 The socio-materialities of renewable energy

While the approach developed here builds upon the analysis of materiality originally developed for the extractive industries, including fossil fuels (Bakker and Bridge, 2006; Kaup, 2014; Kaup, 2008; Bridge and Bradshaw, 2017) the materialities of infrastructure and their changing relationship with territories have attracted a number of contributions. By noting how infrastructures and energy services operate at and across different scales, analysis of the socio-spatial and material forms of energy infrastructures stresses the relationship between urban change and energy transitions (Rutherford, 2014; Rutherford and Coutard, 2014) and suggests how infrastructures are ‘interwoven with the changing material, socio-economic and ecological development of cities and urban regions’ (Graham and Marvin, 2001: 9). In this respect, energy socio-materialities become important in that they point towards the role of the historical legacies of urban/ local energy infrastructures (Karvonen and Guy, 2018), the proximity to geographically fixed resources (e.g. geothermal energy and its relevance for promoting urban heat networks), and the

importance of governance in promoting those material energy assets (Kuzemko and Britton, 2020). Besides, fundamental to a socio-technical system approach to infrastructure is the consideration that 'pipelines, electricity transmission and distribution systems, generating stations and other energy facilities have a politics or create political effects' (Bridge et al., 2018). Many scholars suggest that looking at the coupling between the biophysical and political processes, and how they are shaping and shaped by energy systems, further illuminates the political stakes of energy infrastructure (Jones, 2018; Baka and Vaishnava, 2020) and the potential that infrastructures offer in creating new political arrangements (Rutherford, 2014) and actively enrolling different publics (Barry, 2013).

2.2 The Analytical Approach

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 renewable energy 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 and extent of built infrastructure requirements for RE delivery and the power to shape infrastructure networks*: 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 may enable or limit RE potential, as well as the new infrastructure requirements, including the transportation or distribution network developments required to harness the renewable resource into a marketable form of energy, and the power to shape them.

Our argument here is that these socio-material dimensions can provide us with a more nuanced view of the role of three further factors that interact with RE and policies for its deployment: energy-related *institutions*, *governance* and *infrastructure issues*.

While research has highlighted the central role of institutional variations as foundations for geographical differences in the adoption of RE (Moss et al., 2015; De Laurentis, forthcoming; Wirth, 2014; Jehling et al., 2019; Hansen and Coenen, 2015), the approached used here allows us to focus on the institutions- the 'formal regulations, legislation and economic systems as well as informal societal norms that regulate the behaviour of economic actors' (Gertler, 2004: 7)- that matter for RE and the varied effects that they can exert on regional RE deployment. The regional lens is also useful as it enable us to explore the relationship between different scales of governance of energy infrastructure and network development and how they can contribute to reshaping energy landscapes locally (cf Addie et al., 2020).

The socio-material dimensions of RE also emphasise the range of agencies that may be involved in strategically establishing, contesting and reproducing institutions, expectations, visions and infrastructure as RE deployment unfolds. The dimensions show how socio-material aspects of energy systems can have significant influences on the governance of energy systems, as different local and regional socio-material characteristics can promote variety in energy transitions, influence the capacity of local and regional governments to pursue sustainable energy policies and affect the outcomes of governance (Kuzemko and Britton, 2020; Gailing and Röhring, 2016).

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 infrastructure, and how they can be addressed together, thus facilitating the identification of the policy implications for RE promotion and development in particular regions.

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

Socio-material Dimensions of RE	Institutions	Governance	Infrastructure issues
The appraisal of RE 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 & 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	**Regulation and**	**Regional agency and**	**Local infrastructure**

and extent of built infrastructure requirements for RE delivery and the power to shape infrastructure networks	**standards** Transmission charges (and location pricing) Connection rights/ rules Historical rules and institutions favouring centralized electricity infrastructures and utilities	**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 mobilized through the purposive actions of agents, resulting in the local emergence of new paths.	**development** Centralised power supply vs. decentralized; 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

3.0 Methods

This section aims at setting out the design of the study, the rationale for data collection and analysis. The paper uses case study research design (Yin, 2014) as it is helpful to tease out some different contextual conditions: 'since social, cultural and institutional forces vary considerably across territories, the geographical context of these factors should provide critical input' (Farole et al., 2011: 59). Hence examining the influence of institutions is highly contextual (Wirth et al., 2013). Additionally, it was judged important to analyse case studies both within and between two countries as 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 (Peck, 2003). 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' (Sovacool, 2014: 13).

Consequently, it was decided to perform a comparative case study analysis of three regions in Italy, Apulia, Tuscany and Sardinia and the two devolved territories of Wales and Scotland in the UK. These case studies were selected to allow similarities and differences to emerge and to enable appropriate, valid comparisons to be made: regions and 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 absence for some time of a national energy strategy and 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'. 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 to 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 (De Laurentis, 2013; Cowell et al., 2015). 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 of 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.

To perform the comparisons, 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 (De Laurentis, 2018). 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. 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 infrastructure categories presented in the columns of Table 1. In what follows we present the differences in regional implementation of RE that emerged in the case study analysis by organising the discussion under the three socio- material dimensions identified. We then discuss their relations with institutions, governance and infrastructure and draw out the policy-related insights in Section 5.

4.0 Results

As suggested, this section applies the analysis of the socio-material dimensions to the case studies. Firstly, we organise the discussion around the three dimensions and provide examples of how RE deployment has been influenced in the cases 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 infrastructure have enabled or constrained RE transitions in the cases investigated.

4.1 *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. This reflects the capacity and willingness (or the lack of) of a number of actors both to identify the challenges that RE presents for land use management and to make land available for its development. The differences that have emerged across the regions investigated are detailed next, by looking at their choices in spatial planning approaches.

Forms of spatial planning are often considered valuable policy mechanism to help accelerate the growth of RE deployment and manage the potential disruption to existing land uses and the diverse values attached to them. The processes of weighing resource potential and different environmental values against RE targets are often articulated through deliberation between national, regional and local stakeholders. While planning institutions, at national and regional levels, are often required to mobilise a dominant strategic line around the delivery of specific objectives and guidance, it is the regional government (and the local authority or the municipality) that often engages with local stakeholders and can design and regulate locally tailored implementation strategies in accordance with local and regional

specificities and priorities. Spatial planning therefore can reflect the capacities and willingness of governments to render land available for RE development and manage social response (Cowell et al., 2015). In both Italy and the UK, it is the regional (and local) levels that are tasked with weighing resource potential and different environmental values against RE targets.

In Italy, the national government was set to provide, following the 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)[2]. However, such guidelines were issued in 2010, seven years later than planned, contributing to a great variety of spatial planning approaches for RE at the regional level. This variety resulted in some regions becoming more amenable to large-scale development, while others attempted to restrict the sizes of RE projects (NG IT).

Tuscany adopted a coordinated approach between the regional and the provincial levels, that identified resource potential but also the environmental implications of RE deployment (RC_T IT). Although Apulia lacked coordination among the different spatial levels, it created a fast track approval and simplified licensing system that helped streamline the authorisation process for RE planning, project approval and installation. This provided 'a positive image' of the region, leading to increased interest from RE developers and investors attracted by lucrative national incentives and favourable natural resource conditions (DA IT). An attempt to regulate and limit RE deployment via a Regional Landscape and Territorial Plan was adjudged unconstitutional and abolished by the Italian Supreme Court as it contravened the principle of the Legislative Decree 387/03 (cf. Perrotti, 2015). The Sardinian regional government sought to regulate energy-environmental planning for wind installations via the instrument of moratoriums. These moratoriums 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 for both Scotland and Wales in shaping RE deployment, offering much scope for autonomous policy development and influencing 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 (especially on-shore wind) within its territory, acting as a Welsh 'national zoning framework' (Cowell et al., 2017: 175). TAN 8 offered a supportive policy context for wind power development and was considered, by the wind energy sector, as a 'stabilising condition for investment' (Cowell et al., 2017). Nevertheless, wind deployment has been slower and patchier than in Scotland (see Ellis et al., 2013). To some extent, 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).

Planning is often seen as another ingredient in Scotland's success in delivering RE (Cowell et al., 2013). The Scottish Government played a key role in steering RE consent, by 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. The Scottish National Heritage, responsible for the conservation of landscape and nature in Scotland, has also provided a generally supportive and facilitative stance (Toke, 2014).

These examples show some of the differences that occurred in organising the relationship between RE energy resources and the 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 spatial panning to promote 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 a number of regional actors to render land available for RE development, constructing opportunities for, and barriers against, RE development.

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

Visions: As discussed, different actors can organise and mobilise particular resources, with the aid of, and in relation to, natural resource endowments, creating a particular vision(s) and development path, prioritising interests and mobilising resources for RE generation. In many cases, regions, although they may lack control over economic framework conditions (e.g. subsidies and feed-in tariffs), can mobilise coherent shared visions for the exploitation of their indigenous renewable resources (Essletzbichler, 2012; Späth and Rohracher, 2010; Dawley et al., 2015). Visions can often mobilise actors and resources, influencing which RE-related discourses gain hegemonic status and which are marginalised (Lupp et al., 2014) and how the dominance of other energy sources can dilute or reinforce the power of emerging discourses in favour of RE (Szarka, 2007). Opposing and supporting discourses can also be framed differently at local and national levels via competing conceptualisations of the rural 'resource' (Lennon and Scott, 2015).

There are differences in the way in which the regions under investigation promoted RE deployment, exploiting regional renewable resources for the benefit of their territory, identifying priorities that differ from those at national levels, and prioritising specific RE sources over other energy sources (renewables and non-renewables). RE development in Apulia was seen as an opportunity to alter patterns of economic growth. Breaking the trajectory of fossil fuel path dependence has become a major goal of its regional energy policy, combined with the desire to support RE development rather than the re-introduction of nuclear capacity. Strong signals in this direction were sent by the region's commitment to support the growing number of firms and research capabilities in the RE cluster. Most significant was the way in which the Apulian government streamlined and accelerated the bureaucratic procedures of license concessions, promoting public sector deployment and financial support for the creation of energy 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, as these processes were much less present than elsewhere in Northern Europe and the US (Di Minin et al., 2006). The regional energy plan promoted a new model and vision for Tuscany, the '*Modello Toscana Green*', based on an industrial strategy for RE that would stimulate networking and technology transfer activities between local research institutes and the small and medium firm base. Moreover, in Tuscany, the presence of a higher capacity of RE resources already deployed, such as geothermal and hydro, has 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, have had an important effect on RE deployment narratives. Two major infrastructure projects have *de facto* dominated RE and energy priorities in the region: the construction of a large submarine power cable to connect Sardinia with Tuscany to overcome a condition of *energy isolation* (Corsale and Sistu, 2016); 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, guaranteeing the natural gas supply to the region and helping the national government to deliver a more secure energy system. While the project has currently come to a halt, energy development in Sardinia has been supported and RE developments constrained by an investment argument that could provide the main solution to the national energy security problem.

Scotland and Wales have each produced energy strategies that stress their own regional visions and aspirations for RE development. 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, developing an ambitious strategy for the development and deployment of indigenous natural resources. Post-1998 Scottish independence debates[3] offer an example of how the Scottish National Party, and its leadership, has regarded energy development- and RE- as part of the imagery of an independent Scotland (Dawley et al., 2015; Toke et al., 2013). 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 new-build. A critical mass of actors (e.g. 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 the implementation of projects.

Welsh governments have sought to 'act' on energy as an integral part of their wider economic and environmental agendas and to 'maximise the potential for RE in Wales', based on harnessing the region's natural resources, to attract significant new investment. Nonetheless, there has been a lack of clarity and focus in the economic development thinking of RE policy. Between 2007 and 2011, RE policy was closely tied to climate change policy and since then ministerial responsibility for the energy portfolio has not

been clear. Ministerial drive also lacked in the face of some public dissent towards windfarm and associated infrastructure developments. These factors, to some extent, increased developers' scepticism around the capacity and willingness of the Welsh Government leaders to demonstrate leadership on driving the RE agenda forward, perpetuating the view that there has been a tentativeness regarding the '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 (Cowell et al., 2017).

Similarly, targets and aspiration for RE at different scales have been set for increased levels of electricity production from renewable sources. In both Italy and the UK, there have been differences in the way in which national targets have been delegated to the regional level. Italy adopted a principle of '*burden sharing*' that 'distributed' the national target for RE between Italian regions following a detailed methodology (MISE, 2010). However, the multi-year delays that occurred in the development of such a methodology left the regions to decide on their own targets, indeed whether to set targets at all. Regional targets reflected a fragmented and uncoordinated approach to identify regional RE potential, underestimating technological and legislative developments (RC IT). 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 has become a key feature, and a policy output of devolution, providing an important act of differentiation from Westminster (Cowell et al., 2015). The process of target setting was not influenced by Westminster. Rather they 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 (Cowell et al., 2015). While Scotland managed to meet a succession of its own targets set above the UK norm, acting as a '*positive feedback loop*' (WWF, 2014: 26), in 2012 Welsh ambitions for RE expansion were described as 'a wish list, rather than a concrete action plan for delivery' (De Laurentis, 2012: 1992). Nevertheless, both targets and a timeline for action were considered important to drive RE deployment in Wales (RA W), and following pressures from a number of actors in renewable energy, in 2017, the Cabinet Secretary for Environment Lesley Griffiths announced new targets for energy generation in Wales[4].

Summarising, this section has explored how some regions have sought to capitalise on the opportunities offered by RE deployment to promote clustering activities and to 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 deployment rates and RE paths have been pursued in order to fulfil specific visions and trajectories, showing how specific RE sources can get selected over other energy sources (renewables and non-renewables) and priorities.

4.3 The nature and extent of built infrastructure requirements for RE delivery and the power to shape infrastructure networks

The upgrading of transmission and distribution networks is critical for the successful integration of renewable power (Tenggren et al., 2016). With the expansion of RE capacity, electricity network structures and their management have increasingly become a strategic concern (Sataøen et al., 2015). While the national level plays an important role, most challenges surrounding energy infrastructure provision and governance simultaneously involve various spatial levels (Goldthau, 2014). Managing grid capacity and infrastructure upgrades becomes a site-specific issue that questions the role of the region in steering infrastructure requirements; this includes planning processes and approvals (Balta-Ozkan et al., 2015; Sataøen et al., 2015).

The rapid increase in RE penetration that occurred 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 (IEA, 2016). However, congestion problems have become more evident 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 and their connection to the wider energy network (RG_A). Apulia's regional network capacity relies especially on old 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 significantly above the national average (BURP, 2014). While Tuscany has been affected to some extent 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, while the remaining nine related to the development of 380 kV high-voltage collection stations.

Sardinia has a relatively confined electricity grid with limited interconnection to the Italian mainland, a limited thermoelectric park and a reduced energy demand due to the economic downturn of recent years (Terna, 2017). The network infrastructure also presents some distinctive bottlenecks and weaknesses, including a weakly 'meshed' transmission and distribution line (the meshing of the 380 kV network is non-existent) which caused line overloads and voltage problems (Purvins et al., 2011). Such peculiarities have reduced the opportunities for connection and export of energy, making the energy infrastructure subject to a more severe control from the transmission operator and more liable to limiting dispatch orders (RSE, 2011). These physical constraints represented and continue to represent a limiting factor for RE deployment (Regione Sardegna, 2012; Benini et al., 2011; '*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 main 'external failures' that delayed RE targets achievement (Wood and Dow, 2011). 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 (IEA, 2012). 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'[5], 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 (ENSG, 2012). The Scottish Government's *Electricity Generation Policy Statement* (SG, 2013) highlighted how Scotland expected to have an 'excess generation capacity that can be exported through existing and planned export links' (2013: 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 bottle necks[6].

Wales provides an 'object lesson' of the importance of grid capacity to promote RE generation (Cowell et al., 2013: 38). Both onshore and offshore wind generation connections in Wales, together with the potential connection of a new nuclear power station, have raised regional connection issues, in North and mid-Wales (ENSG, 2012). The TAN 8 planning area in mid-Wales did not contain capacity for large-scale wind developments (Ove ARUP, 2010) 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 and affordable grid infrastructure is considered 'a fundamental enabler to connect the new generation that Wales needs for a prosperous low-carbon future'[7].

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 first National Planning Framework in 2004 for Scotland already contained a section on energy infrastructure and subsequent versions followed suit (Ritchie et al., 2013). The Scottish Government also showed support for the most significant piece of grid reinforcement

(the transmission line from Beauly to Denny). Beyond the immediate and practical management of the decision-making process, the Government provided a clear signal and commitment to the project going ahead, which sustained industry efforts towards RE generation during a heavily contested consenting process (Cowell et al., 2013). The Scottish Government has also played a key active role 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 that 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.

Steering the electricity network, at the regional level, is clearly often problematic. In Italy and the UK there have been underlying differences and similarities in the opportunities, actions, and constraints in infrastructure development, at national level, and in the way in which existing infrastructure and plans for the transmission and distribution network development have been governed. 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 the available infrastructure and its upgrading have posed in these regions.

[2] The code here signifies interview data. Please refer to Appendix 1 for a list of interviewees. The material from the interviews is attributed to the organisation but not the respondents to protect their anonymity.

[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.

[4] Welsh Government, 'Lesley Griffiths high on ambition for clean energy, Cabinet Secretary for Environment Lesley Griffiths today announced new ambitious targets for energy generation in Wales', 28 September 2017, http://gov.wales/newsroom/environmentandcountryside/2017/170928-lesley-griffiths-high-on-ambition-for-clean-energy/?lang=en

[5] '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

[6] See for example the Shetland project for exporting to the UK mainland via a high voltage direct current link: https://www.ssen-transmission.co.uk/projects/Shetland (accessed 05/12/19)

[7] The Cabinet Secretary for Environment and Rural Affairs' Energy Statement, 26/09/2017

http://www.assembly.wales/en/bus-home/pages/rop.aspx?meetingid=4644&assembly=5&c=Record%20of%20Proceedings#C494225

5.0 Discussion

This section is divided into two subsections. The first one discusses the implications of the findings in relation to questions of institutions, governance and infrastructure; the second one discusses how the fine-tuned analysis presented of how regional differences in RE deployment arise and operate in practice, highlights the emergence of policy-relevant insights.

5.1 Discussion 1: Regional institutional settings, governance 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. This has enabled the analysis to show the many ways in which local and regional actors have engaged with RE. We now turn to examine how these socio-materialities of RE provide a more nuanced view of the interplay between institutions, governance and infrastructure issues and how they have enabled or constrained RE transitions in the cases investigated (see Table 2).

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

Socio-material Dimensions of RE	Institutions	Governance	Infrastructure issues
The appraisal of RE 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 & 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 and extent of built infrastructure requirements for RE delivery and the power to shape infrastructure networks	**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.

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 and strategies for the development and exploitation of endogenous renewable resources and used *institutions* such as spatial planning and vision(s) to promote or limit RE expansion. Spatial planning has been utilised with a variety of purposes, for instance aiding and accelerating RE expansion (Apulia) to preserve the historical and 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*, RE targets in two of the Italian regions 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 (cf. Cowell et al, 2015). 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 varied powers to mediate the exploitation of RE, capitalising on regional assets and translating national objectives and targets into concrete agendas for action that reflected regional specificities. Nevertheless, the regional capacity to act is also affected by the region's ability to frame and implement policy and the nation's willingness to grant such agency to regions. This is particularly relevant in the discussion around infrastructure issues. 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 networks 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 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 presented above offers an account of how the socio-material dimensions of RE have influenced the way in which regional actors engage with energy systems, flows and infrastructures in order to meet particular goals. The discussion stresses 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 (cf. De Laurentis, 2020), network infrastructures become an important mediating factor between physical resource endowments and institutional/ governance structures at the regional level.

While the discussion points to how regions have set agendas in RE policy 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 focus on the policy implications that emerged from the analysis.

5.2 Discussion 2: Policy insights for regional renewable energy deployment

The importance of regional and sub-national governments in developing RE policies has been highlighted in the recent RE transitions literature (Bradshaw and de Martino Jannuzzi, 2019; Jehling et al., 2019). 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 subnational 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 (IPCC, 2019) 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 the regional contexts used in this paper and summarised in the socio-material dimensions' framework. 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 if developers seek scale efficiencies through larger projects. There is a need for regional energy 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 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 are important. The roles they play, the coalitions they assemble to promote renewable deployment, and the different interests involved in the framing of RE strategies are crucial. For instance, Scotland's success 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 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 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, policy-makers are often faced with a choice around competing regional visions and expectations. 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. An important question is whether a champion narrative can be identified to convey and translate local/ regional relevance and whether the political will is there to pursue it, often in the face of dissent. On the other hand, the vision(s) promoted need to be nurtured by credible expectations, building from past development (and success) and the actual level of performance if they are to become a convincing path forward. The research has shown that as well as the 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 issues that need consideration for the effective deployment of RE.

Thirdly, the example(s) illustrate that regional political commitment has often been able to overcome lack of formal power and facilitate 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 be very beneficial for RE deployment processes. Such engagements can be effective not only in enabling an extensive exchange of expertise (Lutz et al., 2017) 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 source to user may or may not benefit regional communities along the way. 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 (cf. Jones, 2018).

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 choices and outcomes are shaped in particular places, how these differences arise and operate in practice, and need to be taken into account in policy design and implementation at both national and regional scales.

This paper has offered a conceptual and empirical frame under which the socio-material dimensions of RE and their relationship with institutions, governance and infrastructure can be further explored. These

are identified in an attempt to capture how RE processes are shaped by a constellation of interacting actors, institutional and regulative settings, infrastructure opportunities and constraints, together with the socio-materiality of renewable natural resources. We suggest that this heuristic approach has not only been valuable in helping to explain spatial differences and their policy implications in Italy and the UK but could be adopted for further comparative empirical investigations. Such investigations could identify similarities and differences across a broader range of regions and countries that display distinct resource endowments, institutional settings and approaches to governance. This would also help to further refine and validate the framework through additional testing, and to explore its wider applicability; this would address a potential limitation of this research around the rich but relatively small number of case studies examined here.

6.0 Conclusion

Through comparative case study analysis, this paper set out to find insights for policy thinking and implementation by exploring the influence exerted by the 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 the socio-materialities of RE enable a more fine-tuned analysis of how institutions, governance 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 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 and governance capacity 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 affected 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 outlined 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.

Abbreviations

RE- Renewable energy

Declarations

1. 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.

2. Consent for publication

N/A

3. Availability of supporting data

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

4. Competing interests

The authors declare that they have no competing interests.

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6. 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.

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Appendix

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)

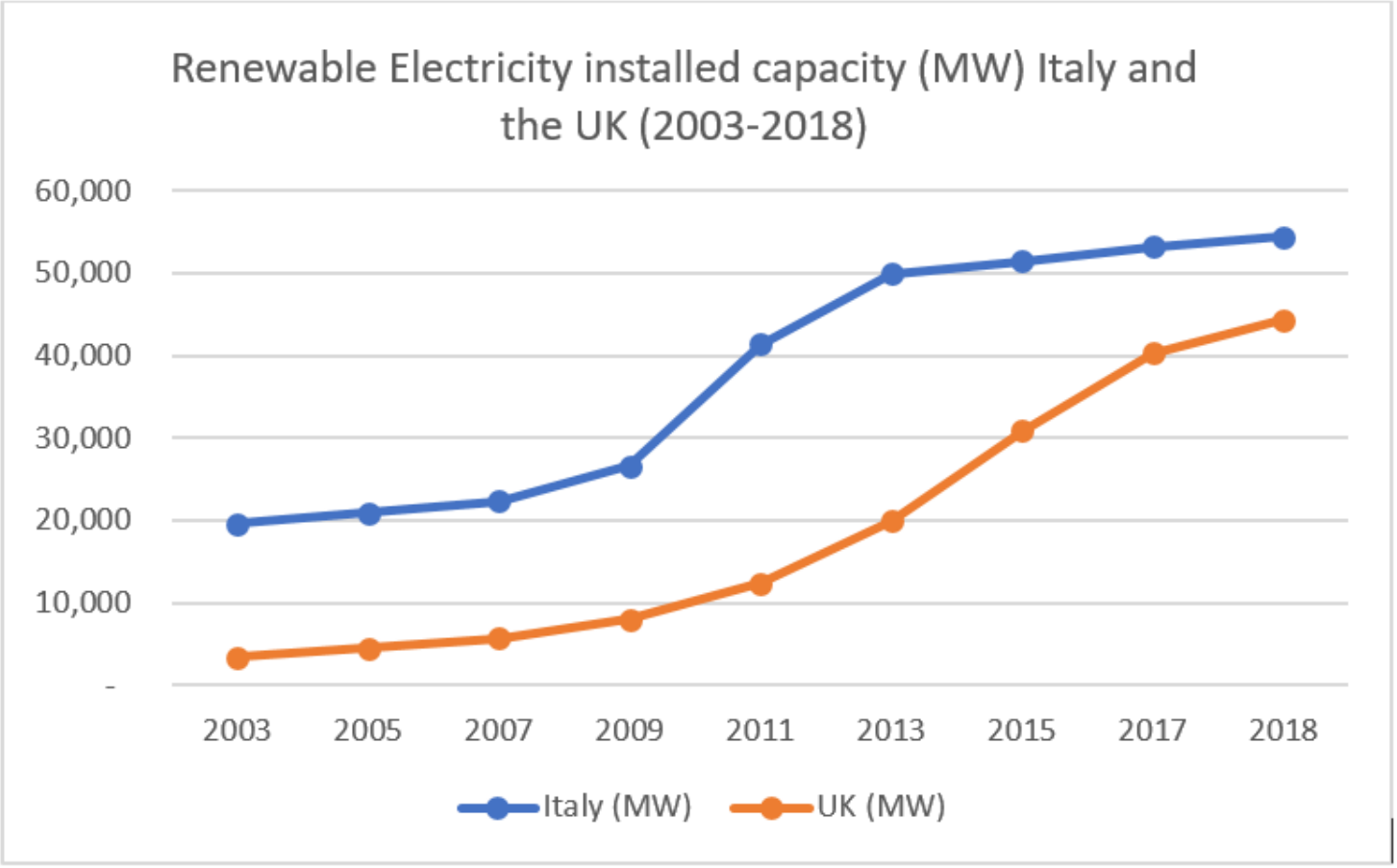
RWE Innogy (Wales) Wind Energy (RB W)

Renewable UK Cymru (RA W)

Swansea University Marine Energy Group (RC W)

Scottish Government (RG S)

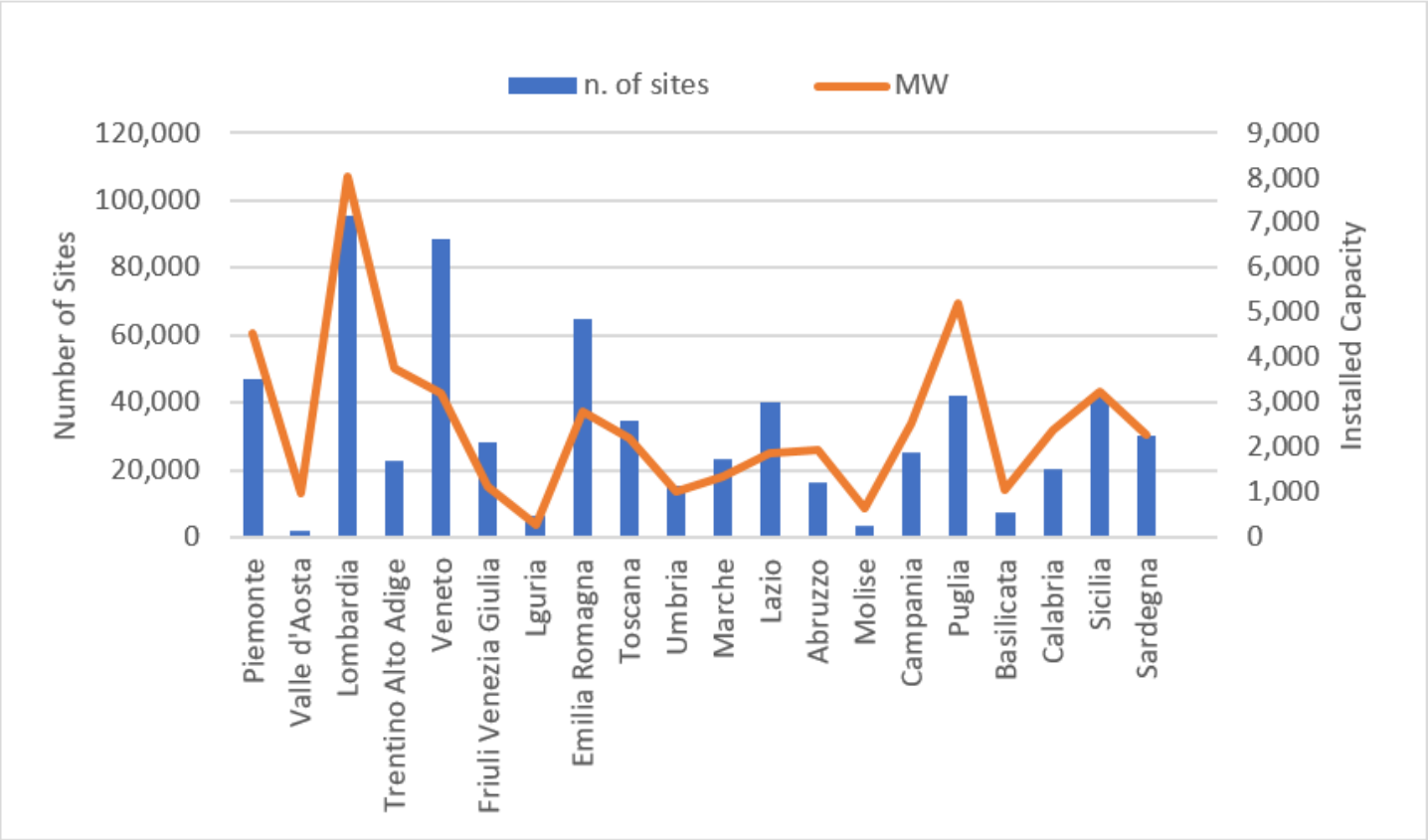
Figures



Sources: GSE, 2018 & BEIS (2018); BEIS (2015). Italian data for 2018 are estimated.

Figure 1

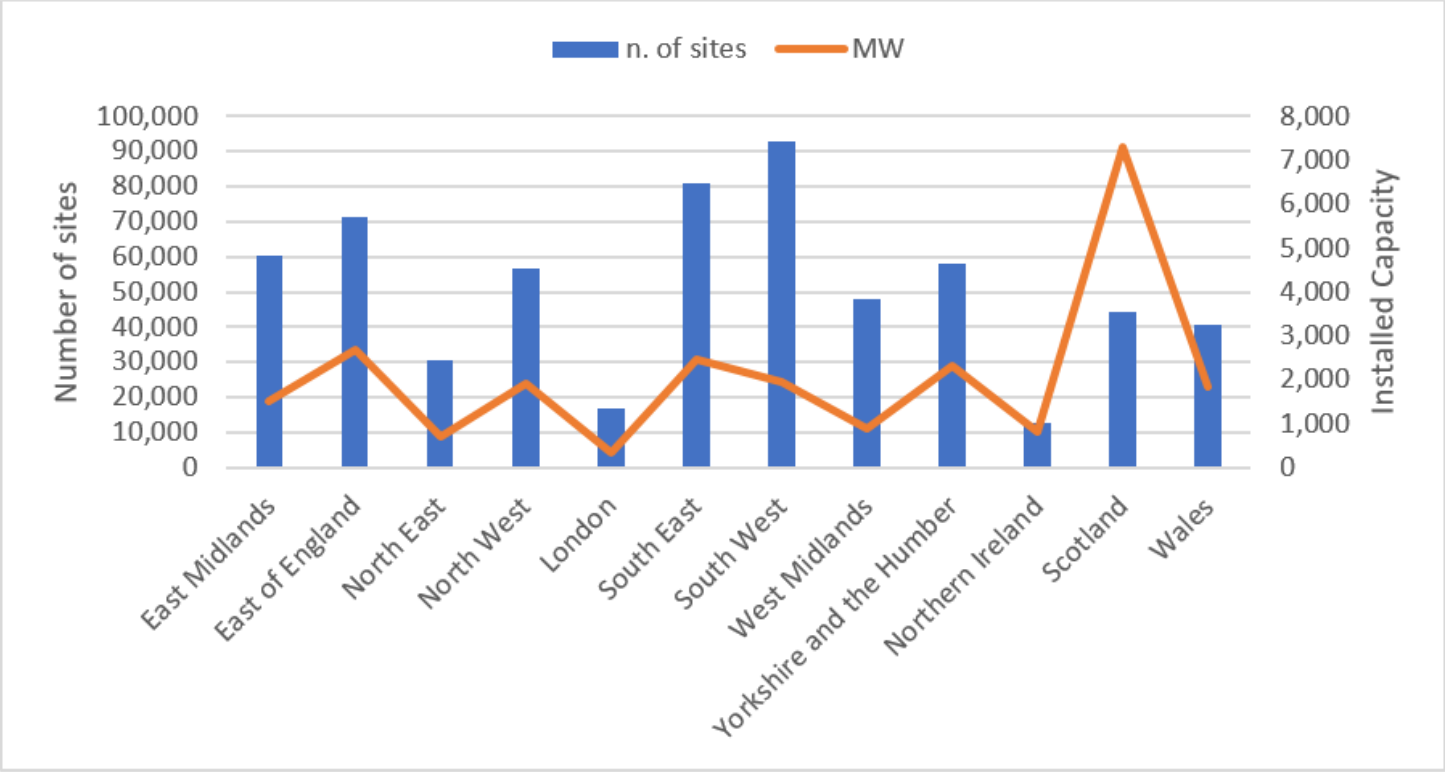
Renewable Electricity capacity (MW) in Italy and the UK



Source: GSE (2016)

Figure 2

Regional distribution of renewable electricity (n. of sites and MW) in Italy (2014)



Source: BEIS (2014)

Figure 3

Regional distribution of renewable energy (n. of sites and MW) in the UK (2014)