'Understanding the material dimensions of the uneven deployment of renewable energy in two Italian regions'

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Abstract

Drawing on empirical material from two Italian regions, we show how various material dimensions have affected the spatial distribution and deployment of RE, in particular solar and wind energy. The paper draws on an approach to the analysis of materiality originally developed in the extractive industries literature, including fossil fuels. RE forms have significantly fewer material components compared with coal, oil and gas and the other extractive industries. The paper acknowledges that RE forms have significantly fewer material components compared with coal, oil and gas and the other extractive industries. Nevertheless, the deployment of RE, the process of turning renewable 'natural resources' into productive use as viable forms of energy through stages of energy conversion, storage, transmission and distribution has material aspects like those involved in the deployment of fossil fuels. This paper aims to show how understanding these aspects of renewable energy offers an opportunity to unpack and explain how particular RE paths come to be favoured or hampered, and yields useful insights into the spatial unevenness and variation of RE deployment at the regional level. Italy has introduced a system of renewable energy incentives, and between 2010 and 2012, has experienced impressive growth in the renewable energy sector. The paper shows how the significant spatial variation in renewable energy deployment in the regions of Apulia and Tuscany can be explained in terms of the influence that the material dimensions exercised in relation to renewable energy deployment processes. The paper suggests that understanding the material

dimensions of renewable energy offers useful insights into how and why RE realises - and quite often fails to realise - its potential in specific forms, spaces and places.

1. Introduction

The deployment of renewable energy (RE) resources presents spatial variations that are not only influenced by the resources' characteristics but also by differing infrastructure endowments and other factors, including geographical, techno-economic, institutional and cultural factors) (de Vries et al., 2007). Flows of renewable resources are thought to be immense in comparison with global human energy use (Johansson et al., 2004), yet their deployment is widely and unevenly dispersed, because of the influence of such factors and their appraisal (Zimmerer, 2013). This spatially unevenness matters, has clear implications for social and spatial justice, and is integrally related to aggregate trajectories of energy decarbonisation.

Drawing on empirical material from two Italian regions, we show how various material dimensions have affected the spatial distribution and deployment of RE, in particular solar and wind energy. The paper draws on an approach to the analysis of materiality originally developed in the extractive industries literature, including fossil fuels. RE forms have significantly fewer material components compared with coal, oil and gas and the other extractive industries. Nevertheless, the deployment of RE, the process of turning renewable 'natural resources' into productive use as viable forms of energy through stages of energy conversion, storage, transmission and distribution through pipes, wires or other form of transport, has material aspects like those involved in the deployment of fossil fuels. This paper aims to show how understanding these aspects of RE offers an opportunity to unpack and explain how particular RE paths come to be favoured or hampered, and yields useful insights into the spatial unevenness and variation of RE deployment at the regional level. Addressing the material dimensions of the deployment of RE is an area that is under-researched (for exceptions see Armstrong and Bulkeley (2014) and Nadaï and Labussière (2012) and also Bridge et al. (2013) in their discussion of the low carbon economy).

The importance of the material dimensions that influence RE are investigated and demonstrated here drawing on empirical evidence from research conducted on two Italian regions, Apulia and Tuscany (in the southern and central area of Italy, respectively). Italy, following pressures from European and international regulation, has introduced RE deployment incentives in the form of subsidies and investment assistance. Generous incentives led Italy to experience impressive RE growth, especially in the PV and wind energy sectors. Italy ranked top worldwide in 2014, alongside Denmark, Spain and Germany, with the largest share of renewable electricity, due to unprecedented increases in PV installation and capacity[1]. Italian regions vary in terms of solar radiation, orography, climate, population, area and economic conditions and share responsibility for energy policies and RE with the Italian central government. Although regions have little influence on the nation-wide level of economic incentives applied to RE[2], the distribution of installed RE capacity has varied significantly across regions. We argue that much of these differences can be explained by the direct or indirect influence of the material dimensions of RE on the deployment processes.

The aim of this paper is to show, with evidence from two Italian regions, how understanding the material dimensions of RE deployment can help analyse and explain the spatially uneven processes of RE deployment. The paper, therefore, has two objectives. Firstly, to explain how consideration of some of the material dimensions addressed by Bakker and Bridge (2006), Bridge (2004, 2009); Kaup (2008, 2014) and others, and originally applied in the geographic resource extraction and fossil fuels literature, can help us identify and focus on those material dimensions that particularly influence RE deployment. Secondly, providing empirical evidence from Apulia and Tuscany, the paper demonstrates the importance of understanding the material dimensions of the deployment of RE and how this helps explain the spatial difference in the uptake of RE in Italy.

The paper proceeds as follows. In section 2, we discuss arguments that address how the literatures on resource geographies and non-renewable resources, especially on mineral, oil and gas exploitation, have acknowledged the role of materiality in energy development. From this brief review, we suggest a number of material dimensions that also influence RE deployment and discuss how this occurs (section 3). In section 4, we introduce the empirical material and the research method adopted for the research. Section 5 discusses the results of the analysis, stressing how engaging with the different material dimensions can unpack how RE resources are- socially and materially- produced in geographically uneven ways. The paper concludes by suggesting that considering the socio-material characteristics of RE deployment is a valuable addition to research that focuses on the organisational and institutional issues of RE diffusion and deployment, helping explain its spatial unevenness at the regional but also potentially at other scales.

2. Material dimensions of non-renewable energy resource deployment

Before illustrating the material dimensions of RE deployment, we draw on some selected contributions from the literatures on resource geographies and non-renewable resources[3], especially on mineral, oil and gas exploitation, that have addressed the complex material dimensions of non-renewable resources. This offers an opportunity to point towards some important material dimensions that, we argue, fossil fuels share with RE resource deployment.

As stated, fossil fuels present much broader material aspects than forms of RE. Nevertheless, bioenergy, which requires biomass feedstocks, and large hydropower and geothermal energy, for instance, all share some materialities with fossil fuels, which largely relate to the material extraction and/or processing of the resource. Yet, even solar and wind energy, while lacking such materialities, also present material dimensions, in particular those associated with processes of energy capture, conversion, transmission and distribution, including the physical infrastructures that support them. These material dimensions not only directly influence RE deployment potential but also interact with the ways in which these physical entities are socially constructed as exploitable energy resources through political-economic and cultural processes (cf. Calvert, 2015). Our argument is that through such processes these material dimensions can and do influence the geographical deployment and dispersion of RE.

Resource and environmental geographers have mostly conceptualised nature in physical terms, traditionally focussing on improving the flow of resources ‘from’ nature ‘to’ society through the design of institutional and territorial frameworks for procuring and managing environmental goods and services (Bakker and Bridge, 2006; Bridge, 2009)[4]. Yet Bakker and Bridge (2006) suggest that what counts as a resource depends on the interaction between its physical quality and condition (e.g. the variable grade/ quality of mineral resources, for example) and social institutions. Referencing the material, they contend, is to acknowledge that 'things other than humans make a difference in the way social relations unfold' (Bakker and Bridge, 2006: 18). In this sense, they continue 'materiality matters because of the way its heterogeneity differentially enables, constrains and/or disrupts the social practices through which resource regulation is achieved' (Bakker and Bridge, 2006: 21). In other words, they acknowledge resources in dialectical terms as a combination of physical and discursive practices- a socio-natural phenomenon- that takes shape through interaction between the material/ physical world and individual activities, institutional agendas and industrial forms of organisation.

Zimmerman's dynamic concept of natural resources that vary over time and space is useful here. (Zimmermann, 1951: 15) argues that 'resources are not, they become: they are not static but expand and contract in response to human wants and human action'. Bridge (2004: 416), in his account of the geography of mining investments, argues, for instance, that the size, location and value of mineral reserves are dynamic phenomena, products of both geological and mineralogical processes and a continual socio-economic re-appraisal of utility and value (Bridge, 2009). Changes in societal demands, in market prices and/ or cost of extraction, exploration activity and/ or the introduction of new technologies can create new reserves in places where, to all practical purposes, none previously existed (Bridge, 2004).

Moreover, Bridge (2008) (see also Bridge and Bradshaw (2017)) has also drawn attention to the materiality of production networks. Using the example of the oil industry, Bridge highlights the influence that materiality exerts on industrial organisations within it. He argues that the production chain of extractive industries is territorially embedded at different points. The industries' materiality emphasises that the dependency on natural production, the location relative to markets, and the existing infrastructure limit the spatial flexibility of the network. Kaup (2008: 1736) arrives at a similar conclusion, indicating that the 'material difficulties of natural gas extraction and transport have shaped the structure of Bolivia's natural gas industry'. The extraction and transport of natural gas requires much fixed capital and technological innovation in extraction and separation processes, pipeline construction and conversion. The requirement of capital, Kaup (2008: 1737) argues, 'has shaped the relationships between transnational extraction firms and the people and places in which natural gas is extracted'. Moreover, looking at the changing regulations and tensions surrounding Bolivia's natural gas, Kaup (2008) shows the importance of recognising how nature can be both materially manipulated and discursively constructed by a diversity of actors to disrupt and secure regimes of accumulation. He reinforces this in Kaup (2014), arguing for attention to be paid on how actors' positions within processes of capital accumulation and their differential relationships with nature can shape the ways they understand and seek to protect their interests.

The discussion above suggests therefore a number of material dimensions that we could explore in understanding RE deployment. These refer to:

1. The physical, technical and socio-economic appraisal of resources, their potential (or the 'quality of the energy resources') and how this interacts with their contextual conditions (e.g. land areas required and their location, land use preferences, land use ownership, land use protection and land cover);
2. The importance of the physical characteristics of natural renewable resources and the requirement of a robust infrastructure to deliver RE can significantly influence RE deployment. This includes the pre-existing built-infrastructure in maximising or limiting RE potential, the infrastructure requirements, the transportation or distribution networks required for harnessing the renewable resource into a form of energy;
3. The discursive constructions, the narratives and visions that actors use to promote their interests, influencing RE deployment, partly by framing or reframing debates on priorities around the deployment of new energy sources.

Table 1 shows a summary of the socio-material dimensions of RE deployment.

Table 1 The diversity of material dimensions that influence RE deployment

<Insert Table 1>

While we have here drawn attention to some material dimensions of fossil fuels that may enhance our understanding of RE deployment and have acknowledged that in general fossil fuels have significantly broader material dimensions than forms of RE, some differences are also relevant. These differences include: those between the renewable and depletable attributes of RE and fossil fuels, respectively; the relatively low life cycle emissions of greenhouse gases and regional or local pollutants associated with some forms of RE, the social construction of which can lead to differences in the socio-political debates and contestations over fossil fuel and RE exploitation and deployment and their consequences.

This section has discussed the dimensions of materiality, as addressed by Bakker and Bridge (2006); Bridge and Bradshaw (2017); Kaup (2008, 2014), and applied in the fossil fuels geography literature and we argue that some of these material dimensions are also relevant to forms of RE. This section has shown also how these material dimensions offer a way of acknowledging resources in dialectical terms - a socio-natural phenomenon that takes shape and form through interaction between the material/ physical world and specific activities, institutional agendas and industrial forms of organisation. Moreover, the paper by Bridge et al. (2013) on the geography of energy transition has to some extent, highlighted already the importance of investigating the socio-material dimensions of the low carbon economy and Calvert (2015)'s paper on 'energy geographies' has stressed the importance of resources and environmental geographies to the study of emerging energy resources. They both use the concept of energy landscape to capture how different modes of energy production, distribution and use are underpinned by material relations and suggest the need to engage seriously with the materialities of renewables. Huber (2015) also reflects on how the deep cultural and political discourses are linked with the materiality of energy systems and the importance of such considerations for alternative energy futures. This paper seeks to contribute to a better understanding of the material dimensions of RE deployment in two Italian regions. The intention is neither to over-privilege material explanations[5] -and revive the ghost of physical determinism- nor to delve into the problematics that surround issues of matter and materiality (Anderson and Wylie, 2009; Kearnes, 2003; Whatmore, 2006).

The question we address next is how understanding the material dimensions of RE offers opportunities to unpack how specific RE resources come to be fashioned in some areas and regions and not in others and hence to help explain the spatial differential in RE deployment at the regional scale.

3. Exploring the material dimensions of RE deployment

The previous section noted how Bridge et al. (2013) on the geography of energy transition and Calvert (2015) on 'energy geographies' drew attention to the physicality of resources, the built infrastructure and narrative and vision of the low carbon economy and the relevance of resource and environmental geographies to the study of emerging energy resources, respectively. In this section, we explore further how the material dimensions just identified influence RE take up and deployment and help explain differences in its spatial distribution.

3.1 RE sources as potentially deployable sources of energy, their appraisal and their interactions with current land-based resource use

As suggested, the deployment of natural renewable resources depends on specific physical, cultural, economic and technological characteristics and their appraisal. Harnessing the natural resource from the sun, the wind, a river or the sea becomes a core feature of any RE project. How natural resources get estimated and valued will influence the nature of investments and returns expected from projects that aim to recast these resources into viable, legitimate sources of energy production (cf. Armstrong and Bulkeley (2014), on community hydro in the UK). Nevertheless, although resource potentials and resource assessment procedures are often presented as 'objective', many are strongly influenced by assumptions about average values and trends that are themselves often affected by the assessments' purposes and the actors involved.

Moreover, in the exploitation and deployment of RE technologies, sometimes apparently unlikely materials, entities and sites are recast as containing the potential for RE generation (e.g. as sites for wind turbines, roof space for solar PV, fields for biomass, etc.) challenging the existing resource use (Armstrong and Bulkeley, 2014). Articulating the materiality of renewable natural resources in terms of resource endowments and energy density (simply defined here as the land requirements per unit of electricity generated from the resource), influences the socio-economic appraisal of resources and their potential. This occurs via the iteration between spatial resource assessment, land use and land protection and negotiation among conflicting land use interests. We explain this below.

In the EU, the introduction of legally binding targets for the share of energy production from renewables has induced unprecedented development of RE policies and RE deployment (Banja M. et al., 2016). It has also given new impetus to the assessment of RE resource availability and hence its materiality. Member States have produced strategies and measures to meet their binding 2020 targets, resulting in scenarios and roadmaps at different spatial levels. The latter have become important tools for future planning of energy investments and supplies and helped identify targets for RE production at the European, national and regional scales. The target setting has been influenced by a sense of urgency about investment in new capacity (Haas et al., 2004; Szarka, 2007). This has led most of the assessments - and the (mathematical) economic models underlying energy policy designs - to rely on the implicit assumption of an homogeneous space differentiated solely by energy gradients (solar irradiation, wind speed, tidal currents, etc.) (Nadaï and van der Horst, 2010a; cf. Shove, 1998).

The problems of this generalisation are evident given that different types of RE can be more or less space-intensive to develop because of their different power densities (Smil, 2010), have highly geographically dependent energy production efficiency (Dijkman and Benders, 2010; Seager, 2009) and they can be variable. For example, significant land space can be required not only for wind and PV farms but also for the construction and maintenance of access roads and buffer zones, and for transmission infrastructure (e.g. rights-of-way and high voltage power lines) if electricity is to be carried to distant urban and industrial areas (Smil, 2010). The spatially extensive nature of some type of RE resource means that pursuing low carbon transitions through renewables may hold profound implications for other goods, services and values attached to the spaces concerned (see for instance Wolsink (2017) on the varied spatial claims of different RE technologies).

Land use, therefore, quickly became 'the most important environmental consideration in the development of these resources' (Pasqualetti, (1990), cited in Walker (1995)). The low energy output per unit area of wind power and the requirements of onshore sites (MacKay, 2009) have created greater potential for extensive disruption of existing landscapes and the values attached to them, spurring research into the evolving relationship between landscape, energy and policy (Nadaï and van der Horst, 2010a; Nadaï and van der Horst, 2010b); see also Bridge et al. (2013)). Competing interests for the potentially multiple uses of land resources engage in an arena of planning systems and institutional infrastructure, socio-cultural characteristics and environmental priorities (Keenleyside et al., 2009). Nadaï and van der Horst (2010a) argue, for instance, that landscape can be understood as a multi-faceted cultural and political process in which technologies and energies are embedded into territories and local communities (Nadaï and Labussière, 2009). The stimulation of RE technologies and development, together with the management of the multiple uses of land and land availability, have prompted a multidimensional debate that encompasses tensions between economic, social and environmental concerns, at the different scales - from local to global - at which these operate (e.g. Walker (1995)).

To sum up, this material dimension points towards the importance of the physical, technical and social and economic appraisal of RE resources and their potential deployment via the iteration between spatial resource assessment and alternative land uses. The negotiation between turning resources into potential sources of RE and the current land resource use provides opportunities but also hindrances for RE deployment. Consequently, the devices used to frame such negotiations become highly important.

3.2 Physical characteristics and built infrastructure requirements for RE deployment

Both the physical characteristics of natural renewable resources and the requirement of a robust infrastructure to deliver RE can significantly influence RE deployment. In relation to the former, RE technologies might emerge and diffuse in one or more places where natural conditions and specific physical characteristics require testing of and learning about technical specificities – e.g. remote, difficult environments for testing sensor technologies for offshore RE. Likewise, technologies might be deployed where enhancements are required to address locally specific problems (e.g. vis-à-vis electrical load transmission capacity, balance management and storage). Managing grid capacity is a scale and site-specific problem; tackling RE resource intermittency/ variability links an inherent material property of (some) renewables to wider conceptions of how electricity networks should operate. Such activities could provide the seedbed for further targeted local, regional and national policy interventions.

Moreover, RE activities can emerge in places where the physical characteristics of the areas surrounding the natural resource make it more practical to harness the renewable source than in other places (e.g. lagoons, sheltered coastline, well-developed grid system and port infrastructure). Moreover, areas with a well-developed grid system and port infrastructure - important characteristics for the commercial success of offshore renewables - and with favourable local weather conditions and local geography, can strongly influence the exploitation of these resources (Murphy et al., 2011).

Infrastructure networks or their absence can enhance or impede RE deployment and delivery. Thus, for example, global, national and regional power and infrastructure networks become intimately connected through the materially embedded transmission grids within specific territories (Hiteva and Maltby, 2014) and any interconnections between them. Similar considerations apply to renewably produced gas or liquids. The built infrastructure, including the built environment, thus becomes an important mediating factor between physical resource endowments and institutional/ governance structures, creating inertia and path dependencies (such as in the case of the national grid infrastructure in the UK that has delayed RE developments: see for instance Wood and Dow (2011)), constraining the feasible innovation trajectories. Moreover, areas with limited infrastructure are less attractive to global investments than those better endowed. This highlights the importance and the challenges of strategic investments in electricity transmission and distribution networks, as the number and volume of distributed RE generation connections increases.

In this respect, this material dimension foregrounds the importance of the specific physical characteristics of renewable resources, the requirement of robust, appropriate infrastructure to transmit and distributes RE electricity, gas or liquids, and how this aspects of materiality can advance or hinder RE deployment.

3.3 Discourses, narratives and visions for renewable energy deployment

While the discussion of this dimension focuses on narratives and visions for deployment, it also picks up on issues connected with resource appraisal discussed in sub-section 3.1 because of their influence on the formations and character of narratives and visions. Resources can be characterised according to both their availability and attributes that relate more directly to their potential deployment. Developments in RE technologies and deployment have been accompanied by new techniques to ascertain the availability and potential of the resources, the economic costs and returns of a particular project, the science and engineering of the technology under investigation and related environmental and social concerns. Yet, 'understanding how, why and by whom calculation takes place, and what is and is not included in such processes' becomes crucial in 'understanding how resources come to be constituted' (Armstrong and Bulkeley, 2014: 68-69).

Because natural resources are both physical and social constructs, resource potential assessment imply that more careful consideration needs to be given to how these calculations happen and the actors involved. In the case of spatial planning for RE, Power and Cowell (2012) argue that some selectivity is integral to combining complex situations into a spatial map that is invariably reductionist. This highlights the need to investigate which resources do or do not become incorporated into spatial representations, and the extent to which these spatial representations are accepted or resisted by different actors. Research on opposition to RE development argues that much of the potential for conflict is not solely technological in nature but lies in the highly contextualised way in 'which (in)compatibility and (un)suitability (of energy and landscape) are perceived, narrated, delineated or negotiated by different stakeholders and the public' (Nadaï and van der Horst, 2010b: 182).

Actors, therefore, can promote or hinder appraisal of resources and their abundance through different storylines (cf. Hajer, 1995). These might narrate the reality to simplify, influence or massage strategic policy priorities (De Laurentis et al., 2016a; De Laurentis et al., 2016b; Teschner and Paavola, 2013). RE resources, for instance, are often represented in terms of 'development zones' or 'opportunity areas', which can obscure or demote alternative claims on the same space.

As argued, climate change and energy security imperatives have spurred a renewed interest in RE deployment, inducing specific configurations of interests (Nadaï and van der Horst, 2010a). This has led to questions about the pace and scale of RE development, including two issues: firstly, the significance of mobilising discourses to attain policy purposes, rally actors and aggregate resources (Szarka, 2007); secondly, it has shifted attention to establishing which RE-related discourses gain hegemonic status and which are marginalised (cf. Lupp et al., 2014). Szarka (2007), for example, offers an interesting account of the development of RE in France, highlighting how the dominance of the nuclear sector has diluted the power of emerging discourses in favour of RE. Lennon and Scott (2015), writing on Ireland's midlands as sites for large-scale wind, also identify how opposing and supporting discourses can be framed differently at local and national levels and are narrated via competing conceptualisations of the rural 'resource'.

Similarly, apparently abundant natural resources may lead to 'imaginative geographies' and reproduce ideas about nation-building, national identity and citizenship and territory (Bouzarovski and Bassin, 2011). Energy sources are often woven into discourses and debates about identity, image and significance of nation states in the global arena, and a nation's or region's visions of its own future development (Perreault and Valdivia, 2010). Such incorporation of identity narratives in the articulation of RE and its technologies can drive the exploitation of natural resources associated with particular energy development paths (cf. Essletzbichler (2012), and Späth and Rohracher (2010)). Visions can also often work to harness particular RE resources to oppose other forms of RE (e.g. when renewables such as wind and solar are promoted to oppose nuclear new built capacity) or vice versa.

In this sense, here we draw attention to the actors, how they create differing vision(s) of identity, at different spatial levels, with the aid of, and in relation to, their appraisal and presentation of natural resource endowments. This material dimension offers the opportunity to broaden the understanding of how RE deployment can fulfil specific visions or trajectories. It does so in two ways: first, it draws attention to the discourses and coalitions that emerge in relation to using natural resources as energy sources, stressing the conflicts, powers, interests and priorities of the actors involved; and, second, it shows how different actors can organise and mobilise particular resources and shape what constitutes an accepted 'legitimate' source of energy.

This section has discussed three material dimensions that can influence the characterisation, assessment and possibilities of RE and help explain differences in its take-up, deployment and spatial distribution. By drawing on empirical material from research conducted on two Italian regions, Apulia and Tuscany, in the next section we provide empirical illustrations of how these material dimensions have affected regional RE deployment and its distribution.

4. RE deployment in Italy: spatial and regional differences

The Italian government has for some time placed a significant emphasis on the mobilisation of RE sources. Consequently, the deployment of RE has been one of the main priorities of Italy's energy policy. A growing RE contribution has been seen as a way to reduce Italy's import dependence (among the highest, globally- the country is heavily dependent on imported fossil fuels and electricity from neighbouring countries), and increase security of energy supply[6]. Following pressures from European and international regulatory frameworks, Italy introduced a system of generous, uncapped incentives (subsidies and investment in RE deployment) that, led Italy to experience, between 2010 and 2012 an impressive growth in the RE sector and an unprecedented increases in PV installation and capacity[7] (see Figure 1). The country, however, displays great variations in the number of RE installations, their type and spatial distribution (see also Antonelli and Desideri (2014). These are particularly evident by region.

Figure 1 Growth of Installed capacity in RE (all sources) in Italy

< Insert Figure 1 here>

To understand these variations, we focus the analysis onto the regional level, for two reasons. Firstly, the country has undertaken constitutional reforms that provided a new framework for sharing regulatory competences between the State and the Regions, with energy becoming an area of 'concurrent legislation' (between the State and the Regions)[8].

While the national government provides an overarching framework for RE development[9] – and the economic incentives for the promotion of RE- regions have responsibility for the areas described in the box below.

Box 1: Areas of responsibility for the regional level

- Formulating political objectives for regional energy and limiting greenhouse gases as envisaged by the Kyoto Protocol;
- The development and exploitation of endogenous resources and renewable resources;
- The location and construction of district heating equipment;
- Issuing of hydroelectric concessions;
- Energy certification of buildings;
- Guaranteeing safety, environmental and territorial compatibility;
- The security, reliability and continuity of regional supplies;
- Making legislative and regulatory provision for authorisation procedures and the operation of energy production plants.

The Regions and the autonomous provincial governments produce their own Regional Energy Environmental Plans (PEARs)[10]. These establish regional energy policy objectives and, while PEARs were adopted as early as 2000, provisions for RE were only made more explicit in later updates. Italian regions also have autonomy in the planning and development of their own innovation and industrial support programmes. Moreover, regions have engaged in EU framework programmes for energy and RE research and demonstration and have specific arrangements for RE research and innovation[11].

The national government was set to provide clear targets both at national and regional levels for the achievement of the European 2020 target and a set of guidelines for the siting of RE plants, under the principle that RE installations (and the infrastructure required for the operation of the plants) were considered of public utility, urgent and could not be deferred (Legislative Decree 387/2003).

The National Action Plan (MISE, 2010) identified 2020 targets for each RE in terms of potential output and power and stressed how the national target for RE would 'be divided between the Italian regions, with shared methods for achieving this target' (MISE, 2010: 4). However, burden-sharing regional targets and the methodology for their calculations, were only published in 2012 (DM, 2012), with a requirement to be incorporated in each region's PEAR. Moreover, the 'Linee Guida' guidelines, under which regions were required to indicate areas and sites unsuitable for the construction of specific types of RE production, were also issued after long delay (in 2010, 7 years later than planned), leaving regions to legislate in their absence, contributing to the emergence of regional differences in identifying resource potential, RE targets and the RE project siting.

Secondly, Italy, except for the Po plain in the north, is a largely mountainous country that runs from the Alps to the central Mediterranean Sea, presenting regional variations in solar radiation, orography, climate, population, area and economic conditions. This regional diversity, with the increased autonomy of action and governance capacity over energy, despite lacking control over economic framework conditions (such as subsidies and feed in tariffs), provides an interesting testbed for and illustration of the three dimensions of materiality. Figure 3 and 4 and table 2 illustrate the differences in terms of wind and solar resources and the regional distribution of RE.

<Insert Figure 3 & 4 Here>

Figure 2 Italian Solar Resources: Regional Differences
Figure 3 Italian Wind Resources: Regional Differences

<Insert Table 2 Here>

Table 2 Regional Distribution of installed capacity (MW) & n. of sites (2014)

This paper is mainly based on research undertaken as part of an EPSRC funded doctoral study conducted between 2014 and 2017. While the study covered 3 Italian and 2 UK regions, in this paper, due to space limitations, we presents only evidence from Tuscany and

Apulia. Data were obtained via documentary analysis and extensive in-depth interviews with a broad range of actors. A total of 20 interviews were undertaken with a number of government officers, civil servants, private and public-sector companies at national and regional levels (see Table 3) engaged in RE activities in Italy; two study visits to Tuscany and Apulia were also conducted during May and October 2015, respectively. A scoping exercise investigated regional differences in RE deployment and resource endowments to aid the selection of regions. While Apulia, in the south, was selected for its pioneering role in RE deployment, as it became the leading region in wind and solar energy production in 2012, Tuscany, in the centre, was selected for its high concentration of universities and research clusters specialising in RE and environment, and its tradition of industrial districts. While similarities and differences in solar radiation and wind strength are displayed in Figure 2 and 3, table 4 (a&b) shows some data on the demographics of the two regions and RE uptake by source.

The paper highlights next how many of the differences in RE uptake in Tuscany and Apulia can be explained in terms of the influence of material dimensions t of RE deployment.

<Insert Table 3 here >

Table 3 Organisations interviewed

<Insert Table 4 (a& b) here >

Table 4 (a) Regional differences: Case Study regions key demographics (Italy)

Table 4 (b) Regional differences: Case Study regions n. of sites and generating capacity by source (2014)

5. Analysing the differences in RE deployment in Tuscany and Apulia

Following the discussion presented above on the material dimensions of RE and how they influence RE deployment, we now apply these propositions and demonstrates the insights that arise, drawing on the empirical evidence from the two regional case studies. The empirical material is organised according to the themes in Table 1, providing some key illustrations of the impact of the differences in the socio-material dimensions of RE sources on the forms and directions of RE deployment. Table 5 summarises the main regional differences that emerge when we consider the material dimensions of RE deployment, using the analytical themes highlighted in Table 1 to organise the discussion.

<Insert Table 5 here >

Table 5 Material dimensions for RE deployment in Tuscany and Apulia

5.1 RE sources as potentially deployable sources of energy, their appraisal and their interactions with current land-based resource use

We have argued that turning resources into viable and legitimate sources of energy disrupts and challenges established notions of the existing land resource, and their extent and potential exploitability. We aim to show how the negotiation between turning resources into potential sources of energy and the current land-based resource use provided opportunities and hindrances for RE deployment in Tuscany and Apulia. This socio-material condition manifested itself via three kinds of differences in: i) targets and resource assessment; ii) planning and the potential and different attributes when compared against RE targets; iii) the availability of land and current land-based value.

Targets and resource assessment: the delays in identifying the share of regional targets under the burden-sharing of the European 2020 target and in the provision of the *Linee Guida* guidelines created a policy landscape based on a legislative and administrative framework of rules that were unclear, often contradictory and that varied across regions (Giannuzzi et al., 2013; RSE, 2011). Both Tuscany and Apulia adopted RE targets before the identification of the burden-sharing objectives (Table 6 a&b summarise the targets developed for the two regions). However, regional targets reflected a fragmented and uncoordinated approach to identify regional RE potential. While targets were developed utilising different approaches to resource potential evaluation[12] (Gianni et al., 2012) and provided different timescale for achievement, in both regions, they did not consider technological and legislative developments, thereby underestimating RE potential and opportunities (Gianni et al., 2012)[13]. Targets, in the Italian regions investigated, were not seen as a specific instrument for evaluating, planning and consenting RE deployment initiatives that could help reaching those targets (cf. Gianni et al., 2012). This is in contrast with the role that targets have played in other regional and subnational contexts in other countries identifying potential capacity for RE natural resource endowment exploitation and driving RE deployment. This for instance is the case of Scotland and Wales, in which targets setting become, as argued by Cowell et al. (2015) a key feature, and a policy output, of devolution, providing an important act of differentiation from Westminster.

<Insert Table 6 a&b here >

Table 6 (a) Regional targets

Table 6 (b) Burden-Sharing: Share of final consumption of energy covered by renewable energy (%) in the regions under investigation

Apulia's PEAR (PEAR, 2007: 133) included 'a target of 8000 GWh (about 4,000 MW of installed capacity) in the wind sector' and '200 MW in PV installed capacity' (PEAR, 2007: 170). Nevertheless, although the wind energy forecasts proved to be in line with the trend recorded over the last few years, photovoltaic forecasts heavily underestimated actual outcome by more than an order of magnitude (with over 2,499 MW installed (PEAR, 2014)). The favourable incentive system attracted the attention of numerous, varied entrepreneurial organisations that proposed, during the peak demand period (end of 2011) 37,000 MW of wind and 18,000 MW of photovoltaic projects (PEAR, 2014). Moreover, by the end of 2012 Apulia had 78% of installed PV capacity generated by large-scale ground-based solar farms nearly twice the Italian average of 43% (Giannuzzi et al., 2013).

Moreover, while Apulia '*started from a situation in 2006 where there was no (or very limited) RE and Apulia is the only region without hydroelectric power that historically* *constitutes the major RE source in Italy*' (Interview ARTI), Tuscany had a higher capacity of RE resources already deployed, such as geothermal and hydro. This helped Tuscany achieve intermediate targets by choosing to invest in micro-generation rather than larger scale deployment. Tuscany is the only Italian region with installed geothermal capacity (this accounts for 36.9% of total RE installed capacity in the region)[14] and '*with respect to the other regions all the goals of 2020 in fact can be achieved by geothermal energy alone*' (Interview SantAnna). This to some extent has influenced the choices made concerning RE deployment and '*limited the deployment of large scale wind and ground- based solar energy initiatives*' (Interview REG Government T).

Planning and the potential and different values of environmental attributes when compared against RE: In Italy, it is often the regional (and local) levels that are tasked with weighing resource potential and different environmental values against RE targets. As noted, the regions have legislated in the absence of national rules for the siting of RE plants. In these circumstances, some regions were more amenable to large-scale development and achieving targets, while others restricted the sizes of RE development.

Tuscany was the '*first region in Italy to have identified a methodology, which included digital maps and geo-referenced data, to identify RE potential in the region*' with the '*aim of reducing CO^2 emissions' (*Interview Unisi*).* This approach, adopted as early as 2000 and published in the region's PER, not only spelt out *'the environmental implications of RE deployment*' (Interview Unisi) but was shared at the provincial level so that '*each provincial plan, following the same methodology, included efforts that could contribute to achieving regional objectives*' (Interview Unisi).

Apulia published its PEAR in 2007, but unlike Tuscany, no provinces and few municipalities produced their own energy plans. This created confusion as the authorisation procedures and operation of energy production plants are the responsibility of the regional level, whereas responsibility for the environmental impact evaluation resides at provincial and municipality levels. It also diminished the regional government's role in coordinating RE deployment. Moreover, in 2008 Apulia created, a fast track approval and a simplified licensing system that helped streamline the authorisation process for RE planning, project approval and installation. This provided '*a positive image of the region as an investment actuator*' (Interview ARTI). The Simplified Authorization Schemes implied that '*RE projects of* *up to 1MW could be authorized with a simple authorization to build issued by the municipalities*' (Interview Regional Government A)[15].

For both solar and wind energy, this led to an increased interest from RE developers and investors attracted by lucrative incentives and plentiful natural resource conditions[16]. As seen, solar radiation is above the national average in much of Apulia, with a yearly irradiation of 1 679 kWh/ m2 (the highest in Europe (ARTI, 2008). Wind resources are also good concentrated in the north of the region, where the wind speed averages 6/7 meters per second (OECD, 2012) . While these areas are '*less constrained on the landscape than other areas such as those in Abruzzo with its National Park, the mountains area and Tuscany'* (Interview REG government A), the municipalities in the areas, which perform administrative functions (e.g. planning and authorisation for the construction and operation of RE plants, in coordination with the regions), played a dominant role. Some municipalities stood to gain from RE projects through the rent of the land (on average €5,000/ MW/ year) but also via generous royalties from developers (between 3 and 5% of RE generation and turnover)[17]. In Foggia, Apulia, a small municipality with 2000 inhabitants and 90 MW of installed capacity benefitted from royalties between €800,000-1,000,000 (RSE, 2011).

Apulia attempted to regulate RE planning and limited the development of certain areas with the approval of the Regional Landscape and Territorial Plan in 2008, a provision adjudged unconstitutional and abolished in 2010 by the Italian Supreme Court (Perrotti, 2015)[18]. In the absence of the *Linee Guida*, regions were not permitted to legislate in this area. Once the *Linee Guida* were published, the region's Regional Landscape and Territorial Plan was re-published (in 2010); this prohibited, the installation of ground based PV plants on agricultural land, authorising them only on the roof tops of greenhouses and other agricultural structures in industrial and/or urban areas. This triggered resistance to large-scale deployment, albeit when an impressive level of installed capacity had already been achieved.

In Tuscany, by contrast, the 2000 regional PER already identified the RE potential and identified the environmental implications of RE deployment. Moreover, an integral part of *Piano di Indirizzo Energetico Regionale* (PIER (2008)- the updated PER for the region) provided a maps of landscape and archaeological constraints, of electric lines and of the average wind speed, to inform the spatial location and distribution of RE projects.

The availability of land and current land-based values: Apulia is mostly characterised by flat areas and small hills, with 83 % of territory being agricultural land. It is the '*availability of agricultural land*' (Interview CREA) in the region that has played an important part in its RE development path. Land availability acted as a 'land reservoir' for PV and wind plant installations especially since the first national feed-in tariff system was implemented in 2005 (cf. Perrotti, 2015). Many interlocutors have highlighted this characteristic of the area, coupled with the availability of optimal wind speed and solar irradiation, as '*an ideal territory*' (Interview Regional Government A; Interview Uni Foggia) for the expansion or RE. The small size of farms, with the consequent fragmentation of agricultural land and the issue of generational renewal, combined with agricultural production base on arable/ wheat farming, have characterized the agriculture sector's economic crisis. RE has been therefore regarded as a '*financially interesting alternative income source*' (Interview Uni Foggia) and a 'major factor in thwarting economic crisis and social isolation of rural activities' (Perrotti, 2015)[19].

In contrast, Tuscany is characterised by an agricultural sector that uses the land for '*not intensive crops*', supporting higher-end '*niche'* agriculture productions (Interview CRIBE) and where '*the landscape discourse is fundamental and an integral part of the region*' and '*it is always difficult to have the authorizations by the responsible bodies for so many types of interventions*' (Interview REG government T). Moreover, the regional energy plans (2000, 2008 and 2015) stressed that RE development and deployment in the region stem directly from the negotiation between the drive towards a low carbon economic agenda that can harness local natural resources and the need to protect the importance of the historical, cultural and artistic characteristic of the regional territory. This provided limits to and constraints on RE deployment.

5.2 Physical characteristics and built infrastructure requirements for RE deployment

We have discussed how the exploitation of potential RE sources is influenced by the presence or absence of established infrastructure networks. As RE capacity increases, the current infrastructure and the relationship that regions can establish with those who own, operate and regulate it can help reduce the constraints on RE development. Here we differentiate two aspects of this material dimension: i) the infrastructure requirements and ii) the formal regulatory powers and political legitimacy to shape infrastructure networks.

Infrastructure Requirements: During the past decade following the very rapid development of renewable electricity production capacity, especially on-shore wind and ground-based solar farms that require connection to the national high voltage grid, the Italian electricity system suffered from inadequate grid infrastructure, which led to frequent curtailment of power (mainly wind) to avoid grid congestion. Congestion problems have become more evident in Southern Italy, including Apulia, where most of the plant installations are concentrated and where the network has a more limited transport and distribution capacity. The electricity network was configured for the long-distance transmission of major electricity flows, mainly from the north to the south, and capacity is lacking in many of the more remote, municipal areas, in which renewables have been deployed. Apulia's regional network capacity relies especially on old 150 kV lines, which do not allow the dispatch of all the power produced[20].

Thus, the overwhelming number of RE initiatives in in Apulia resulted in negative effects on the national electricity system that were not appropriately covered by the PAN 2010 and increased the pressure, at the regional level, to overcome the impact of the plants and their connection to the wider energy network. In 2009, for instance, a significant number of wind farms operated at well below capacity, while others were shut down completely. Moreover, areas of optimal wind resources (along the Foggia-Benevento area) attracted installations without the relevant connection permits, resulting in further network congestion of the. In Apulia, pending connection requests relate to about 30,000 MW of wind power plants and about 6,000 MW of photovoltaic systems. They represent almost 50% of the entire national figure, 3-4 times larger than those of other southern regions and significantly above the national average.

While Tuscany has been affected to some extent by infrastructural issues, the 2014 Development Plan of TERNA, which owns, manages and regulates the transmission grid, shows that against the two interventions necessary in the north and in the centre of Italy, Apulia required 12, 3 of which were for new interregional interconnections and the remaining 9 relate to development of 380 KV high-voltage collection stations.

The formal regulatory powers and political legitimacy to shape infrastructure networks: The infrastructure requirements have institutional concomitants that also problematize regional steering. The transmission grid is a regulated natural monopoly. The development and construction of new facilities (for example, transmission lines and power plants) require permits mandated by state and regional legislation to ensure environmental protection and compatibility with existing infrastructure. The process for obtaining such approvals is regulated by a combination of state and regional legislation and depends on the nature and location of the facility to be realised and the permits required. The process is usually led by the regions (or sometimes the provinces), which co-ordinate the process involving all the agencies and authorities whose consent or opinion is required to finalise the process. Here, the key elements in the upgrading of the transmission and distribution networks have become:

i) systematic investments in the sector by Terna, the national and the regional governments. As noted, from Terna's Development Plan, Apulia is one of the regions that most requires urgent upgrade. Importantly, funding for infrastructure renewal have also been channelled via European structural and convergence funds;
ii) the willingness of regional governments to give the authorisations necessary for the upgrading, and negotiating the public opposition to extensive network upgrade. This highlights another dimension of the difficulties of reconciling RE resource exploitation with existing land uses;
iii) the relationship that regions can establish with network managers to better address and overcome issues related to development. Apulia has instituted a 'concertation table' with the different organizations involved in the programming of the enhancement of the electricity distribution network infrastructure.

While both Tuscany and Apulia engage in research on smart grids and storage in order to strengthen the infrastructure network, because managing the grid is a scale and site-specific problem, the characteristics of the Apulia region make it suitable for testing and piloting innovative solutions. Recently, a 39 MWh EU FP7-funded pilot plant for hydrogen-based storage for grid balancing was opened in Troy, in the province of Foggia, an area with many wind and photovoltaic plants where production peaks and power grid limitations mean energy cannot be locally used or transported.

5.3 Discourses, narratives and visions of abundance and opportunities

We have shown how different actors can construct, organise and mobilise particular natural resource endowments, creating a particular vision(s) and development paths, prioritising interests and recasting resource abundance in terms of their energy generation potential. Here we refer to how actors (i) mobilised and promoted certain imaginaries and visions for RE development and/or used RE resources (ii) to promote specific RE paths vis-à-vis alternative energy sources.

Imaginaries and visions for RE development: Apulia is at the heart of the South – the Mezzogiorno – and often considered as part of a group of chronically poor regions mired in developmental problems, especially unemployment, emigration of economically active people, inefficient public administrations, *clientelistic* political systems and a burgeoning black economy. The region has tried to shed this image by building a reputation for giving priority to good governance, efficient public administration and regional development policies. It was made clear, since the PEAR, that Apulia's abundant natural resources could provide a means to overcome the current patterns of uneven development. According to ARTI (2008: 12) 'for a region like Apulia, the capacity to combine local development with the affirmation of a new energy paradigm (..) would be a big opportunity for energy requalification, production reconversion and development'.

Capitalising on favourable geographical conditions meant RE developments could provide opportunities to alter patterns of economic growth and development. Breaking out from fossil fuel path dependence has therefore become a major regional energy policy goal: the public sector – through a combination of green public procurement, more permissive planning regulations and the deployment of EU funds – has attempted to revolutionise the region's productive structure. It was hoped that rapid RE adoption of would trigger a productive dividend through diversification into new sectors, such as PV panel production, monitoring and experimentation, eco-tourism, and low carbon transport.

Therefore, the PEAR became an iconic document that stated the political commitment of Apulia's president Nichi Vendola's ecologically conscious but development minded political administration, it was seen as an opportunity for a poor Mediterranean region to assume a leadership role in RE (see also De Laurentis et al. (2014) and Altavilla and Morgan (2014)). Strong signals in this direction were also sent in the PEAR (which, according to Vendola, provided 'a new way of land management where ecology moves along with the economy, questioning the dictatorship of fossil fuels in favour of renewables'), and the regional government's commitment to map firms and research capabilities in the RE sector, re-branded 'La Nuova Energia'. Nevertheless, most significant was how the regional government influenced the process of implementation by simplifying and accelerating the bureaucratic procedures of license concessions in 2008 to fulfil this regional vision. With public sector deployment and financial support for energy parks, PV installations and large PV panel manufacture, Puglia was rapidly able to re-sell electricity to the national grid and achieve grid parity.

By Contrast, Tuscany is often presented as an example of Italy's main weakness: that technology transfer processes from university to industry are not as intense as experienced elsewhere in Northern Europe and the US (Di Minin et al., 2006). This despite a high concentration of universities, national, public and private, research centres and research consortia present within the region. The measures adopted for the diffusion of RE in Tuscany were primarily aimed at overcoming this problem, '*diagnosed as a lack of industrial leaders and projects*' (Interview DTE T). The regional energy plan PIER promoted a new model and vision for Tuscany, the '*Modello Toscana Green'*, based on an industrial strategy for RE that would stimulate interactions between companies and local institutions, knowledge and technology transfer processes and specific localisation dynamics and network relations in the RE (and energy efficiency) sector. The publication of the 2008 PIER, of the strategic programme of the RE cluster (Distretto Tecnologico Energie Rinnovabili-DTE), and the creation of the Renewable Energy and Energy Saving Innovation Pole (PIERRE) point towards a clear narrative for promoting the opportunities for the region, capitalising on its rich research expertise.

RE paths vis-à-vis alternative energy sources: we have already pointed to the role that the endowment of geothermal resources played in Tuscany in influencing directions of RE development and its deployment at a large scale. By contrast, in Apulia, the RE development path received more favourable consensus following the debate over the re-introduction of nuclear capacity. In 2008, the Italian government's policy towards nuclear changed and a substantial new nuclear build programme was planned, aiming to generate 25% of the country's electricity from nuclear power by 2030 (later overturned in the 2011 Referendum that rejected nuclear energy). As legislation progressed to identify a framework for siting nuclear plants, the possibility that regions like Apulia might be identified as suitable for the new nuclear plants attracted objections. The Apulia regional government was the first to vote against new nuclear plants and banning, by regional law, the construction of new nuclear reactors in its territory. The region, by '*rejecting nuclear power with a regional law, has shown that it has an enlightened vision of its future energy*' and as Apulia already '*largely contributes to the Italian energy needs, we want to become leader in renewable energy production'* (Interview REG government A), emphasizing the distinct nature of its vision for the region.

6. Concluding Remarks

This paper aimed to show, with empirical evidence from two Italian regions, the material dimensions of RE deployment and how these can help understand and explain the spatially uneven processes of RE diffusion and deployment. We argued that paying attention to these material dimensions can yield additional insights into how and why RE deployment realises- and quite often fails to realise- its potential.

Drawing on empirical material from research on two Italian regions, Apulia and Tuscany, we have provided empirical illustrations of how the material dimensions have affected regional RE uptake. We have shown how resource potential and capacity interact with the actors and the contextual conditions in which the resources are developed and deployed. These processes challenge current land-based resource use and interact with established infrastructure networks, creating opportunities and barriers at different spatial scales. In Italy, RE deployment has been driven mainly by market forces aimed at exploiting resources, and has been favoured by support mechanisms that ensured often generous remuneration for investment in various RE projects. Such development was based on a legislative and administrative framework of rules which were inadequate, uncertain and often contradictory and that varied across regions.

Apulia responded to the introduction of the feed-in-tariffs more promptly than the rest of the country, setting up ambitious deployment policies, facilitating and simplifying approval and licensing system. Generous, uncapped, feed in tariffs, a vision formulated for Apulia to assume a leadership role in the RE stakes and to alter patterns of economic growth and a desire to support RE development rather than the re-introduction of nuclear capacity in Italy- supported RE deployment, especially at large scale. Furthermore, a declining agricultural sector based on wheat cultivation has provided further opportunities for RE deployment. Nevertheless, the very rapid development of electricity production capacity from renewable sources created significant congestion problems, emphasising the limited capacity of regional governance to steer network upgrades and the difficulties of reconciling the exploitation of potential RE resources with existing land uses.

By contrast, Tuscany, with higher RE capacities, such as geothermal and hydro resources, already deployed and characterised by landscape discourses that are an integral part of the regional 'fabric', managed to limit and constrain large scale deployment. RE development and deployment in the region is promoted following an industrial strategy that seek to strengthen the interaction between local companies and research organisations, knowledge and technology transfer processes and network relations in the RE sector. The empirical evidence shows the insights that arise from addressing the socio-material dimensions of RE deployment.

Three issues might usefully be addressed by future research. Firstly, the paper offers several analytical themes under which the material dimensions of RE deployment can be explored. These are identified in an attempt to capture how RE deployment is shaped by a constellation of interacting actors, institutional and regulative settings - and in an effort to understand the social and physical factors that influence how and why RE technologies are dispersing geographically. We suggest that this heuristic has not only been valuable in helping to explain spatial differences in Italian regions but could be adopted for further comparative empirical investigations. Such investigation might identify similarities and differences across a range of spaces, places, scales and countries that display distinct resource endowments and institutional settings.

Secondly, to understand spatial variations, we have, in this paper, focused our analysis on the regional level, as in Italy both regional and national governments have legislative powers for energy and RE. In Italy, regions are an important spatial level at which to investigate RE deployment. Consequently, the Italian regions are an important spatial level at which to investigate RE deployment. As discussed, although Italian regions have little influence on the level of economic incentives for RE, they have been able to influence RE deployment to accommodate regional material differences influencing the pace, scale and outcomes of RE deployment. The paper has shown that in Italy 'regional governments' have exercised the powers to mediate exploitation of RE versus other resources, adding geographical contingency to resource 'availability'. Moreover, infrastructures for transmission and distribution have mediated the extent to which regions are bounded spaces for organizing the terms of exploitation. The scale at which RE deployment is investigated matters, therefore, and will depend on the nature of the source and associated technologies rather than on any single scale for all renewables (see also Smil (2017a, 2017b); Stremke and Koh (2010)). Nevertheless, the paper shows that there is a need to further investigate the role that regions play as spaces that bring together the material with socio-cultural, economic and political configurations and resources in powerful ways, especially as RE – perhaps more than fossil or nuclear fuel cycles – today often seems to dangle the prospect of greater autonomy and control over energy futures for regions (hence the '100% Renewable Energy Region' agenda).

Thirdly, drawing on work from the literature on the material aspects of resource geographies and non-renewable sources, the paper has explored the similarities between some of the complex materialities of non-renewable resources and the material relations and characteristics of RE - particularly those associated with energy capture, conversion and distribution-. Further research is needed to develop a greater understanding of the nature and implications of the similarities and differences between non-renewables and renewable energy sources.

This paper offers an addition to previous research that aims to investigate the spatial unevenness of RE deployment processes. We hope that, following the useful suggestions by Bridge et al. (2013) and Calvert (2015), scholars and analysts of energy transitions, especially those engaged in understanding the role of geographical processes in energy systems, might find it useful to reflect further on the influences that materiality can exert on the uneven processes of RE diffusion and deployment.

Endnotes

1 The installed PV power in Italy was negligible until 2007. A series of feed-in-tariffs and good solar radiation favoured rapid growth.

2 Solar feed-in tariffs were high enough to make a PV plant economically feasible even in the least insolated areas of northern Italy (Antonelli and Desideri, 2014) (cf. Antonelli and Desideri, 2014).

3 For reasons of space, we do not explore these debates in detail here. Hence, this discussion acknowledges but does not include important contributions such as those of political ecologists such as (Huber, 2015) and discussion around material politics (see for instance (Birch and Calvert, 2015), (Barry, 2013; Daunton and Hilton, 2001) that have all discussed aspects of energy and materiality.

4 This stands in contrast with much work in political ecology (e.g. see Bulkeley (2005); Neumann (2009); (Robbins, 2012)) and the production of nature thesis, in which the mutual production of 'society- nature' relations has been central to research and analysis.

5 The natural environment has often been seen as a source of regional comparative advantage. Within the human geography literature, resource extraction (mining, oil and gas, etc.) is underpinned by the classical theory of comparative advantage in international trade as an agent of regional development ((Gunton, 2003; Watkins, 1963)). However, empirical evidence has led to considerable controversy (reviewed in Bridge, 2008).

6 The National Renewable Energy Action Plan (MISE, 2010) in line with Directive 2009/28/EC lists the main objectives of renewable energy policy in Italy as: increasing energy supply security and reduction in energy costs for businesses and individual citizens, promotion of innovative technology, environmental protection (reduction in polluting and greenhouse gas emissions), and therefore, ultimately, sustainable development.

7 In 2009 the share of energy from renewable sources in gross final consumption was according to the (IEA, 2010) 5.2.%, with Italy reaching the 2020 targets (set at 17% of Italy's final energy consumption, 4 years earlier than planned. Renewable energy represented 68.4% of total energy production in 2015, up from 61.9% in 2010 and 46.4% in 2005(IEA, 2016).

8 The country is organised into 20 Regions, including four autonomous Regions and two autonomous Provinces. The constitutional reform gave greater policy authority to the Regions, notably relating to policies with impacts on climate change, energy efficiency policies, as well as infrastructure planning, development and consenting processes.

9 Until 2013, Italy lacked a compelling National Energy Strategy with a clear long-term national vision for the development of the energy sector - and the exploitation of RE sources.

10 From 2001 the Regional Energy Plans (PERs) were called Regional Energy and Environment Plans (PEARs), recognising the role that these plans needed to play for the reduction of greenhouse gases and requiring a

strategic environmental assessment of the measures included in the plans. The PEAR is a reference frame for public and private agents with energy initiatives in an Italian region.

11 Tuscany and Apulia, have set up several regional institutions in support of RE, including the *Agenzia regionale per la technologia e innovazione* (ARTI- Apulian Development Agency), which includes energy among its key sectors,and in Tuscany the *Distretto Energie Rinnovabili* (Renewable Energy District) and *Polo Innovazione Energie Rinnovabili* (an innovation and R&D hub developed to promote firms' collaboration in RE).

12 Even at national level, there was not a uniform study that provided an estimate of Italian RE resource potential. This is often estimated utilising research from the *Fondazione per lo Sviluppo Sostenibile*, a study conducted by ERSE in 2010 and the ANEV's study on the Italian potential of Wind Resources in 2008. The potential estimated in these studies is higher than the potential identified in the PAN (MISE, 2010) (Gianni et al. (2012).

13 Both regional targets (before and after the burden-sharing) were superseded in Apulia by the intermediate period of 2016 while Tuscany is set to achieve its burden-sharing targets by 2020 (see table 6b).

14 Both geothermal and hydro accounts for 52.8% of total installed capacity (respectively 36.9% and 15.9%).

15 However, many larger initiatives were 'artificially fractioned' into less than 1 MW plants, eluding the requirements for lengthier procedures

16 Moreover, the problems and lengthy delays in the authorisation procedures allowed for the emergence of an intermediary, known as the '*sviluppatore'*. The *sviluppatore* has local knowledge, manages the relations with the territory, proposes projects and negotiates with the local and regional governments, and acquires the authorisation, navigating through the complexity of the system. Once the authorisation is in place, they would sell the 'authorised project' to project developers who would then implement and manage the RE installations. This created a market of authorisations. The sviluppatori are in many ways seen responsible for the speculative bubble in RE deployment in Italy (RSE, 2011).

17 The Linee Guida published in 2010 prohibited this custom and introduced a system of environmental compensation mechanisms. These are defined during the Conferenza dei Servizi, proposed by the concerned municipalities, on the basis and in respect of any particular regional plans but cannot unilaterally be defined by a single municipality.

18 Similarly, many other regional laws and norms that sought to regulate RE deployment and its environmental impact issued up until 2010 were also considered unconstitutional and abolished (cf.(Battiato, 2014). This has deprived RE developers of a clear, uniform, transparent framework for siting. This hiatus prompted the national government to submit a bill to restore legislative power to the central government in energy matters concerning projects and infrastructure of national importance. Such an amendment, still under consideration at the time of writing, would not exclude the regions from decision-making processes but would return the legislation in these sectors to one single level and simplify the authorisation process ((MISE, 2013).

19 Not many official statistics are available that show the percentage of agricultural land used for RE installations; an estimate presented by ARPA Apulia shows that, already in 2009, 738,323 MW come from a total agricultural area of 2,214 hectares.

20 Only since 2005 have 132/150 KV networks been included in the national transmission network and so in the transmission system operator's network planning (Gianni et al., 2012).

List of Tables

Table 1 The diversity of material dimensions that influence RE deployment

Socio-material dimensions	**RE sources as potentially deployable sources of energy, their appraisal and their interactions with current land-based resource use**	**Physical characteristics and built infrastructure requirements for RE deployment**	**Discourses, narratives and visions for renewable energy deployment**
Analytical themes	Targets and resource assessment: their construction and assessment Planning for RE & Potential and different values of environmental attributes when compared against RE targets Availability of land/ current land-based values	Infrastructure requirements Formal regulatory powers and political legitimacy to shape infrastructure networks	Imaginaries and vision for RE development How RE are represented vis-à-vis alternative energy sources

Table 2 Regional Distribution of installed capacity (MW) & n. of sites (2014)

Region	n.	MW	n. %	MW %
Piemonte	46878	4,541.10	7.14	8.98
Valle d'Aosta	2082	967.70	0.32	1.91
Lombardia	95353	8,048.50	14.53	15.91
Trentino Alto Adige	22794	3,764.00	3.47	7.44
Veneto	88483	3,220.00	13.48	6.36
Friuli Venezia Giulia	28271	1,119.30	4.31	2.21
Lguria	6662	266.80	1.02	0.53
Emilia Romagna	64693	2,816.10	9.86	5.57
Toscana	34468	2,223.10	5.25	4.39
Umbria	15190	1,023.90	2.31	2.02
Marche	23310	1,339.00	3.55	2.65
Lazio	40094	1,865.10	6.11	3.69
Abruzzo	16426	1,967.30	2.50	3.89
Molise	3589	669.00	0.55	1.32
Campania	25156	2,554.10	3.83	5.05
Puglia	42155	5,219.90	6.42	10.32
Basilicata	7363	1,048.20	1.12	2.07
Calabria	20471	2,407.70	3.12	4.76
Sicilia	42385	3,265.50	6.46	6.45
Sardegna	30390	2,268.50	4.63	4.48
total Italia	656213	50,594.80	100.00	100.00

Source: GSE, 2016

Table 3 Organisations interviewed

			Organisation type		
			Government	*Industry*	*Research (public or private)*
Italy	National		MISE, Department of energy of ministry of economic development	ENEL Green Power (Enel Group subsidiary for renewable sources) Graziella Green	ENEA, National agency for new technologies energy and sustainable economic development CNR (National Research Council) institute of geosciences and earth resources ENEL Research Centre (Global Generation Division) Horizon 2020 Representative for Italy in the area of Secure, Clean and Efficient Energy
	Regional	Tuscany	Department of Energy and Environment, Regione Toscana	DTE Toscana (technological districts for Energy Toscana Region) Magma Energy Italy, geothermal 40 South Energy, marine/ wave energy	CRIBE, Research Centre for Biomass energy, Pisa university, Department of Civil and Industrial engineering Scuola Superiore Sant'Anna, Innovation and Renewable Energy Research Group University of Siena
		Apulia	ARTI, Agenzia regionale per la tecnologia e l'innovazione (Puglia development agency) Puglia Regional Government	Vestas Tara (energy efficiency/ smart buildings)	CREA, Centro Ricerche Energia e Ambiente, Lecce University Foggia University, Economics Department

Table 4 (a) Regional differences: Case Study regions key demographics (Italy)

	Italy (total)	Apulia	Tuscany
area (km2)	301316	19358	22994
population	60782668	4090266	3750511
density	201.72	211.30	163.11
KW/ GVA € Millions 2011	35.75	83.30	23.42

Sources: Istat (2012); Eurostat, authors' calculation from GSE (2014)

Table 4 (b) Regional differences: Case Study regions n. of sites and generating capacity by source (2014)

	Italy (total)		**Apulia**		**% of total**		**Tuscany**		**% of total**	
renewable energy	**n. of sites**	**generating capacity (MW)**	**n. of sites**	**generating capacity (MW)**	**n. of sites**	**generating capacity (MW)**	**n. of sites**	**generating capacity (MW)**	**n. of sites**	**generating capacity (MW)**
hydro	3432.0	18417.5	6.0	2.3	0.1	0.0	159.0	353.9	4.6	1.9
solar PV	648418.0	18609.4	41527.0	2585.9	6.4	13.9	34048.0	739.8	5.3	4.0
wind	1847.0	8703.1	572.0	2339.3	31.0	26.9	89.0	121.9	4.8	1.4
geothermal	34.0	821.0			0.0	0.0	34.0	821.0	100.0	100.0
bioenergy	2482.0	4043.6	50.0	292.3	2.0	7.2	138.0	186.4	5.6	4.6
wave and tidal										
total	656213.0	50594.6	42155.0	5219.8		**10.3***	34468.0	2223.0		**4.4**

Sources: GSE (2014)

* percentage of Total RE regional generation capacity on total Italian

Table 5 Material dimensions for RE deployment in Tuscany and Apulia

Socio-material dimensions	RE sources as potentially deployable sources of energy, their appraisal and their interactions with current land-based resource use	Physical characteristics and built infrastructure requirements for RE deployment	Discourses, narratives and visions for renewable energy deployment
Analytical themes and regional differences	Targets and resource assessment: *Tuscany: targets to 2020 could be achieved with geothermal alone.* *Apulia: in 2006 there was little RE and Apulia is the only region without hydroelectric power.* Planning for RE and potential and different values of environmental attributes when compared against RE targets *Tuscany: has a low carbon economic agenda to harness local natural resources and emphasises the need to protect the importance of the region's significant historical, cultural and artistic characteristics.* *Apulia: Adopted a fast-track approval system and a simplified licensing system that helped streamline the authorisation process for the planning and approval of RE projects and their installation.* Availability of land/ current land-based values *Apulia: the large agricultural sector provides a land reservoir and the region is less constrained in terms of the landscape than Tuscany and other areas like Abruzzo, with its National Park and mountains.'* *Tuscany: places significant value on the environmental (as well as the economic and recreational) potential of the alternative use of land.*	Infrastructure requirements *Apulia: has more evident congestion problems than Tuscany, in the places where most of the plant installations are concentrated and where the network has a more limited transport and distribution capacity (reliance on 150KV lines) - 12 major infrastructural interventions are planned in Apulia alone.* *Tuscany: infrastructure requirements are less evident and governed under the principle of harmonization of territorial planning for the protection of the landscape.* Formal regulatory powers and political legitimacy to shape infrastructure networks *Apulia: congestion problems emphasise the problem of regional governance to steer network upgrade and to take up the opportunities offered by concerted action between the national and regional levels.* *Apulia: acts as a test-bed for innovative solutions to network problems*	Imaginaries and vision for RE development *Apulia: the abundance of natural resources offers a potential means to overcome the current patterns of uneven development.* *Tuscany: RE presented with a narrative that promotes the opportunities for the region to capitalise on its rich research expertise and to stimulate networking and technology transfer activities among the local research institutes (public and private) and the small and medium firm base.* How RE are represented vis-à-vis alternative energy sources *Apulia: in support of an anti-nuclear campaign* *Tuscany: the role of geothermal energy is currently dominant, and tend to limit further investment in wind and solar.*

Table 6 (a) Burden Sharing: Share of final consumption of energy covered by renewable energy (%) in the regions under investigation

Apulia	PEAR 2007 targets to 2016	(i) Halves, between 2004 and 2016, the growth trend of regional energy consumption with respect to the preceding fifteen years (from +19.3% to +9.9%) (ii) increasing the contribution of renewable energy as a percentage of the total regional production from 3% in 2004 to 18% in 2016; (iii) provide electrical energy production from renewable sources of about 8,000 Giga Watt Hours (GWh) for 2016 (rather than the forecast amount of 5,000 GWh); (iv) reach 150 MW of installed solar photovoltaic power
Tuscany	PER 2000 targets to 2010	- 300 MW of potential for wind installed capacity - 6 MW of potential for PV installed capacity - 1080 MW of potential for geothermal energy - 364 MW of potential for hydro energy
	PIER 2008 targets to 2020	(i) Reducing greenhouse gas by 20% in 2020 (ii) to create the condition to produce up to 50% of electricity through the use of renewable sources, including: a. a maximum of 300 MW of wind installed capacity; b. 700 MW of offshore wind; c. 700 MW of PV capacity d. 100 MW additional geothermal capacity (medium enthalpy systems)

Table 6 (b) Burden Sharing: Share of final consumption of energy covered by renewable energy (%) in the regions under investigation

	Predicted 2012*	Predicted 2013*	Predicted 2020*	2012	2013	2014
Tuscany	9.6	10.9	16.5	14.4	15.4	15.8
Apulia	6.7	8.3	14.2	12.2	15.1	14.4

* DM 15/03/2012

Source: GSE, 2016

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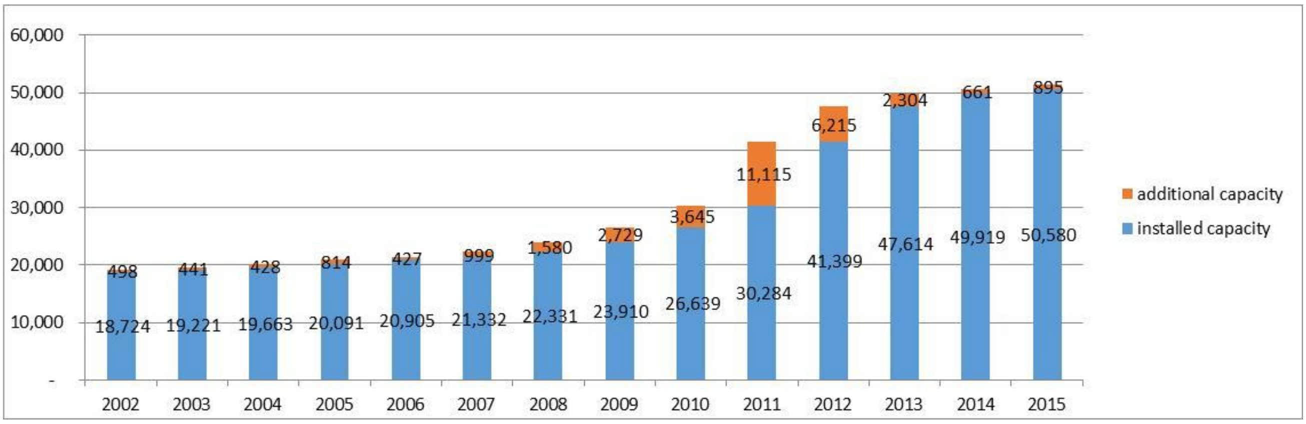
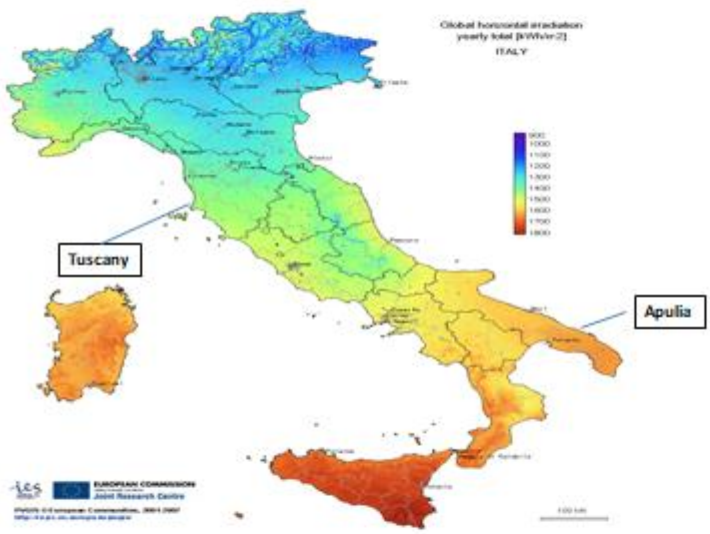
Figure 1 Growth of Installed capacity in RE (all sources) in Italy



Source: GSE, 2015

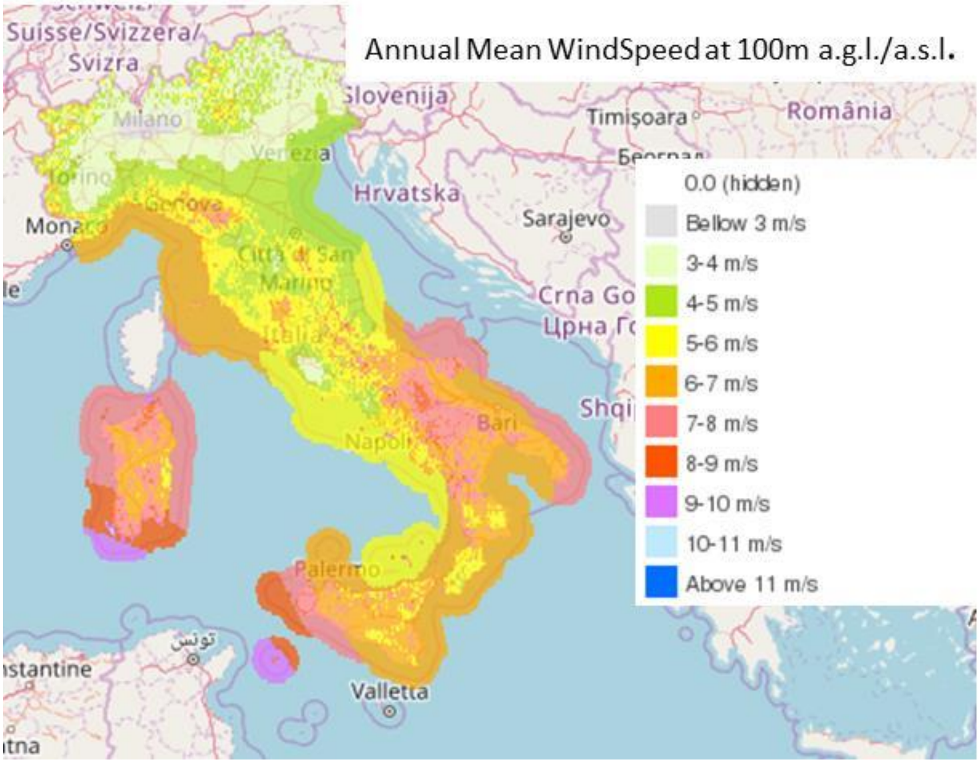
Note: The graph also shows the additional growth in capacity separately for each year.

Figure 2 Italian Solar Resources: Regional Differences



Source: Joint Research Centre/ European Commission

Figure 3 Italian Wind Resources: Regional Differences



Source: This map is generated by the Global Atlas for Renewable Energy (http://www.Irena.org/GlobalAtlas) using Open Street Map (openstreetmap.org) as base map

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List of References

Altavilla E, Morgan K, 2014, "The “Greening” of Puglia: Regional Resilience in the Mezzogiorno?", (Cardiff University, Cardiff)

Anderson B, Wylie J, 2009, "On geography and materiality" *Environment and Planning A* **41** 318-335

Antonelli M, Desideri U, 2014, "The doping effect of Italian feed-in tariffs on the PV market" *Energy Policy* **67** 583-594

Armstrong A, Bulkeley H, 2014, "Micro-hydro politics: Producing and contesting community energy in the North of England" *Geoforum* **56** 66-76

ARTI, 2008, "Le energie rinnovabili in Puglia", in *Quaderni Arti* (Agenzia Regionale per la tecnologia e l'innovazione, Bari)

Bakker K, Bridge G, 2006, "Material worlds? Resource Geographies and the 'matter of nature'" *Progress in Human Geography* **30** 5-27

Banja M., Monforti-Ferrario F, Bódis K, Jäger-Waldau A, Taylor N, Dallemand J, Scarlat N, 2016, "Renewable energy deployment in the European Union: Renewable energy in the European Union further to Renewable Energy Directive reporting, Vol. 3", (Luxembourg)

Barry A, 2013 *Material Politics: Disputes Along the Pipeline* (Wiley, London)

Battiato C, 2014, "Regioni ed energie rinnovabili: ancora una volta la scure della Corte costituzionale si abbatte su norme regionali relative alla localizzazione di impianti di energia da fonti rinnovabili", Ed C Online (Consulta Online)

Birch K, Calvert K, 2015, "Rethinking ‘Drop-in’ Biofuels: On the Political Materialities of Bioenergy" *Science and Technology Studies* **28** 52-72

Bouzarovski S, Bassin M, 2011, "Energy and Identity: Imagining Russia as a Hydrocarbon Superpower" *Annals of the Association of American Geographers* **101** 783-794

Bridge G, 2004, "Mapping the Bonanza: Geographies of mining investments in an era of neoliberal reform" *the Professional Geographer* **56** 406-421

Bridge G, 2008, "Global Production Networks and the Extractive sector: Governing Resources-Based Development" *Journal of Economic Geography* **8** 389-419

Bridge G, 2009, "Material Worlds: Natural Resources, Resource Geography and the Material Economy" *Geography Compass* **3** 1217-1244

Bridge G, Bouzarovski S, Bradshaw M, Eyre N, 2013, "Geographies of energy transition: Space, place and the low-carbon economy" *Energy Policy* **53** 331-340

Bridge G, Bradshaw M, 2017, "Making a Global Gas Market: Territoriality and Production Networks in Liquefied Natural Gas" *Economic Geography* **93** 215-240

Bulkeley H, 2005, "Reconfiguring environmental governance: Towards a politics of scales and networks" *Political Geography* **24** 875-902

Calvert K, 2015, "From ‘energy geography’ to ‘energy geographies’" *Progress in Human Geography* **40** 105-125

Cowell R, Ellis G, Sherry-Brennan F, Strachan P A, Toke D, 2015, "Rescaling the Governance of Renewable Energy: Lessons from the UK Devolution Experience" *Journal of Environmental Policy & Planning* 1-23

Daunton M, Hilton M, 2001 *The politics of consumption: Material culture and citizenship in Europe and America* (Bloomsbury Publishing, Oxford)

De Laurentis C, Eames M, Hunt M, 2016a, "Retrofitting the built environment ‘to save’ energy: Arbed, the emergence of a distinctive sustainability transition pathway in Wales " *Environment and Planning C: Government and Policy* 1-20

De Laurentis C, Hodson M, Marvin S, 2016b, "Retrofit in Greater Manchester and Cardiff: Governing to Transform or to Ungovern?", in *Retrofitting Cities: Priorities, Governance and Experimentation* Ed M a M Hodson, S. (Routledge, Abingdon) pp 34-51

De Laurentis C, Morgan K, Eames M, 2014, "The role of regions in low carbon transitions dynamics: the ‘Greening’ of Puglia Region", in *9th International Conference on Regional Innovation Policies* (Stavanger)

de Vries B J M, van Vuuren D P, Hoogwijk M M, 2007, "Renewable energy sources: Their global potential for the first-half of the 21st century at a global level: An integrated approach" *Energy Policy* **35** 2590-2610

Di Minin A, Lazzeroni M, Piccaluga A, 2006, "Economic growth in knowledge intensive emerging areas: the high-tech cluster in Pisa", in *Regional Development in the Knowledge Economy.* Eds P Cooke, A Piccaluga (Routledge, Oxford (UK))

Dijkman T J, Benders R M J, 2010, "Comparison of renewable fuels based on their land use using energy densities" *Renewable and Sustainable Energy Reviews* **14** 3148-3155

DM, 2012, "DECRETO Ministeriale 15 marzo 2012 'Burden-Sharing'", Ed M d S Economico (Gazetta Ufficiale, Rome)

Essletzbichler J, 2012, "Renewable Energy Technology and Path Creation: A Multi-scalar Approach to Energy Transition in the UK" *European Planning Studies* **20** 791-816

Gianni A, Ferringo R, Stigliani P, 2012, "Rapporto sullo sviluppo delle fonti energetiche rinnovabili nelle regioni del Mezzogiorno", (Fondazione Cercare Ancora, Roma)

Giannuzzi L, Valori L, Basosi G, 2013 *Lo chiamavano il Paese del Sole Il fotovoltaico italiano tra spontaneo insediamento e pianificazione* (Aracne, Rome)

Gunton T, 2003, "Natural Resources and Regional Development: An Assessment of Dependency and Comparative Advantage Paradigms" *Economic Geography* **79** 67-94

Haas R, Eichhammer W, Huber C, Langniss O, Lorenzoni A, Madlener R, Menanteau P, Morthorst P E, Martins A, Oniszk A, Schleich J, Smith A, Vass Z, Verbruggen A, 2004, "How to promote renewable energy systems successfully and effectively" *Energy Policy* **32** 833-839

Hajer J, 1995 *The Politics of Environmental Discource: Ecological Modernisation and the Policy Process* (Clarendon Press, Oxford)

Hiteva R P, Maltby T, 2014, "Standing in the way by standing in the middle: The case of state-owned natural gas intermediaries in Bulgaria" *Geoforum* **54** 120-131

Huber M, 2015, "Theorizing Energy Geographies" *Geography Compass* **9** 327-338

IEA, 2010, "Energy Policies of IEA Countries - Italy 2009 Review", Ed IEA (International Energy Agency, Paris)

IEA, 2016, "Energy Policies of IEA Countries - Italy 2016 Review", Ed IEA (International Energy Agency, Paris)

Johansson T B, McCormick; Kes, Neij L, Turkenburg W, 2004, "The Potentials of Renewable Energy: thematic Background paper", in *International Conference for Renewable Energies* (REN21 Renewable Energy Policy Networks, Bonn)

Kaup B Z, 2008, "Negotiating through nature: The resistant materiality and materiality of resistance in Bolivia's natural gas sector" *Geoforum* **39** 1734-1742

Kaup B Z, 2014, "Divergent paths of counter-neoliberalization: materiality and the labor process in Bolivia's natural resource sectors" *Environment and Planning A* **46** 1836-1851

Kearnes M B, 2003, "Geographies that matter : the rhetorical deployment of physicality?" *Social & cultural geography.* **4** 139-152

Keenleyside C, Baldock D, Hjerp P, Swales V, 2009, "International perspectives on future land use" *Land Use Policy* **26, Supplement 1** S14-S29

Lennon M, Scott M, 2015, "Opportunity or Threat: Dissecting Tensions in a Post-Carbon Rural Transition" *Sociologia Ruralis* n/a-n/a

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

MacKay D, 2009 *Sustainable Energy- whitout the hot air* (UIT, Cambridge)

MISE, 2010, "Piano di azione nazionale per le energie rinnovabili (direttiva 2009/28/CE) ", Ed M d S Economico (Ministero dello Sviluppo Economico, Rome) pp 1-210

MISE, 2013, "Strategia Energetica Nazionale", Ed MISE (Roma)

Murphy J, Lynch K, Serri L, Airdoldi D, Lopes M, 2011, "Site Selection Analysis For Offshore Combined Resource Projects in Europe, Offshore Renewable Energy Conversion - Co-ordinated Action, " (ORECCA, Brussels)

Nadaï A, Labussière O, 2009, "Wind power planning in France (Aveyron), from state regulation to local planning" *Land Use Policy* **26** 744-754

Nadaï A, Labussière O, 2012, "Le paysage éolien, décentralisation énergétique et paysagère, " in *Paysages de l'électricité* Ed c Bouneau, Varaschin, D., Laborie, L., Viguié, R., Bouvier., Y., (Peter Lang, Bruxelles) pp 185-202

Nadaï A, van der Horst D, 2010a, "Introduction: Landscapes of energies" *Landscape Research* **35** 143-155

Nadaï A, van der Horst D, 2010b, "Wind power planning, landscapes and publics" *Land Use Policy* **27** 181-184

Neumann R, P.,, 2009, "Political Ecology: theorising scale" *Progress in Human Geogrpahy* **33** 398-406

OECD, 2012 *Puglia, Italy* (OECD Publishing)

PEAR, 2007, "Regional Plan for Energy and Environment (PEAR) Piano Energetico Ambientale Regionale Regione Puglia", (Regione Puglia, Bari)

PEAR, 2014, "Regional Plan for Energy and Environment (PEAR) Piano Energetico Ambientale Regionale Regione Puglia", Ed R Puglia (Regione Puglia, Bari)

Perreault T, Valdivia G, 2010, "Hydrocarbons, popular protest and national imaginaries: Ecuador and Bolivia in comparative context" *Geoforum* **41** 689-699

Perrotti D, 2015, "Of other (energy) spaces. Protected areas and everyday landscapes of energy in the southern-Italian region of Alta Murgia. ", in *Renewable Energies and European Landscapes: Lessons from Southern European Cases,* Eds M Frolova, M J Prados, A Nadaï (Springer, Dordrecht) pp 193-215

PIER, 2008, "Piano di Indirizzo Energetico Regionale (PIER), Regione Toscana", Ed R Toscana (Regione Toscana, Firenze)

Power S, Cowell R, 2012, "Wind Power and Spatial Planning in the UK", in *Learning from Wind Power, Governance, Societal and Policy Perspectives on Sustainable Energy* Ed J Szarka, Cowell, R., Ellis, G., Strachan, P., Warren, C., (Palgrave Macmillan, London) pp 61-84

Robbins P, 2012 *Political Ecology 2nd Edition* (Wiley-Blackwell, Chichester)

RSE, 2011, "Energia eolica e sviluppo locale Territori, green economy e processi partecipativi", (Ricerca Sistema Energetico - RSE SpA, Rome) pp 1-173

Seager T P, Miller, S.A., Kohn, J.,, 2009, "Land Use and Geospatial Aspects in Life Cycle Assessment of Renewable Energy", in *IEEE International Symposium on Sustainable Systems and Technology* (IEEE, Tempe, AZ, USA)

Shove E, 1998, "Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings" *Energy Policy* **26** 1105-1112

Smil V, 2010, "Power Density Primer: Understanding the Spatial Dimension of the Unfolding Transition to Renewable Electricity Generation (Part I –Part 5)", http://www.vaclavsmil.com/wp-content/uploads/docs/smil-article-power-density-primer.pdf

Smil V, 2017a *Energy Transitions: Global and National Perspectives.* (Praeger, Santa Barbara, CA)

Smil V, 2017b *Energy: A Beginner's Guide(2nd Edition)* (Oneworld Publications, London)

Späth P, Rohracher H, 2010, "'Energy regions': The transformative power of regional discourses on socio-technical futures" *Research Policy* **39** 449-458

Stremke S, Koh J, 2010, "Ecological Concepts and Strategies with Relevance to Energy-Conscious Spatial Planning and Design" *Environment and Planning B: Planning and Design* **37** 518-532

Szarka J, 2007, "Why is there no wind rush in France?" *European Environment* **17** 321-333

Teschner N, Paavola J, 2013, "Discourses of Abundance: Transitions in Israel's Energy Regime" *Journal of Environmental Policy & Planning* **15** 447-466

Walker G, 1995, "Energy, land use and renewables. A changing agenda" *Land Use Policy* **12** 3-6

Watkins M, H., , 1963, "A Staple Theory of Economic Growth" *Canadian Journal of Economics and Political Sciences* **29** 141-158

Whatmore S, 2006, "Materialist returns: practising cultural geography in and for a more-than-human world" *cultural geographies* **13** 600-609

Wolsink M, 2017, "Co-production in distributed generation: renewable energy and creating space for fitting infrastructure within landscapes" *Landscape Research* 1-20

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** 2228-2244

Zimmerer K S, 2013 *The New Geographies of Energy: Assessment and Analysis of Critical Landscapes* (Taylor & Francis, New York & Abingdon, Oxon)

Zimmermann E, 1951 *World Resources and Industries, 2nd revised ed.* (Harper and Brothers, New York)