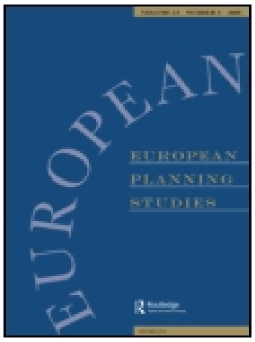

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Jürgen Essletzbichler

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Renewable Energy Technology and Path Creation: A Multi-scalar Approach to Energy Transition in the UK

JÜRGEN ESSLETZBICHLER

Department of Geography, University College London, Gower Street, London WC1E 6BT, UK

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ABSTRACT *This paper examines the potential contribution of UK regions for developing and deploying renewable energy technologies to achieve the government target of obtaining 20% of its energy from renewable sources by 2020. The paper argues for a multi-scalar approach to energy transition theory and policy. National-scale processes and policies need to be complemented by regional and local policies in order to discover and incorporate meso-level sources of renewable energy, recognize that niche or path creation is a geographically localized process and mobilize heterogeneous, local actors around common "regional energy visions" to improve implementation of renewable energy projects. After critically reviewing the main theoretical approach to energy transitions, the multi-level perspective, the paper employs patent data to describe the comparative position of UK regions in the renewable energy sector and examines the success of Danish, German and Spanish regions resulting from strong government intervention at the national level supplemented by region-specific strategies. A number of policy strengths and shortcomings are identified in the evolutionary trajectory of the UK energy system including weak technology push and policy pull factors. Finally, the paper reviews existing regional renewable energy policy and speculates on the potential impact of recent changes in spatial and energy policies on the ability to deploy and develop renewable energy sources in the UK.*

Introduction

In order to limit average global temperatures to 2°C above pre-industrial levels, global carbon emissions need to be limited to a cumulative total of 750 Gt CO_2 between 2010 and 2050 (Broeckner, 2007; Messner *et al*., 2010). The key driver to approximate this goal is the decarbonization of the energy sector. Assuming a modest growth rate of 1.6% per year between 2008 and 2050 implies an electricity supply of 39,000 TWh in 2050 (Jacobsson & Bergek, 2011). Given the currently installed capacity of renewable and nuclear energy sources of 6600 TWh (International Energy Agency, 2011) entails

Correspondence Address: Jürgen Essletzbichler, Department of Geography, University College London, Gower Street, London WC1E 6BT, UK. Email: j.essletzbichler@ucl.ac.uk

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the installation of additional renewable capacity of 32,000 TWh which is five times the capacity of the whole power sector in 1973. The task is enormous and requires the search for new technologies and implementation of all existing renewable energy technologies (RETs) immediately with the goal of a transition from carbon to RETs in a relatively short period of time. The UK has committed to supply 20% of its energy from renewable sources by 2020 demanding rapid transition from a fossil-fuel-based energy system to one powered by renewable sources.

The dominant theoretical framework on transition (Geels, 2002; Smith *et al*., 2010) is strongly influenced by evolutionary economics, in particular, the work by Neo-Schumpeterians on technology regimes, paradigms and trajectories (Dosi, 1982; Freeman & Perez, 1988), the systems of innovation literature (Lundvall, 1992; Nelson, 1993) and work on co-evolution (Norgaard, 1994; Nelson, 2001), and proposes a multi-level perspective (MLP) to conceptualize transitions where new technological pathways are created in socio-technical *niches* operating outside the dominant socio-technical *regime* that are also influenced by *landscape* processes such as resource scarcity, peak oil, energy security or economic crisis. The theoretical framework has subsequently been broadened to recognize the interdependence between the evolution of the technological, economic, environmental, social and political subsystems with strong recent emphasis on actor-network and discourse analysis of existing policies (Shove & Walker, 2007; Walker, 2008; Walker & Devine-Wright, 2008). This paper will critically review this literature and identify the strengths and a number of shortcomings with the approach, in particular, the lack of attention to spatial scale, and employ insights from evolutionary economic geography to argue for a multi-scalar analysis of transitions in general, and energy transitions in particular.

MLP is employed to examine the transition towards renewable energy supply in the UK with a particular emphasis on the regional scale that has received little attention in the literature (for an exception, see Smith, 2007). As regional transition processes are linked to decisions taken at the national scale, it is impossible to understand the UK's energy transition without first discussing niche development and landscape pressures for the UK as whole. For this purpose, the UK is compared with the most successful countries in the European Union (EU): Denmark (DK), Germany (GE) and Spain (SP). While causality is difficult to establish, DK, GE and SP are all characterized by successful regional clusters in RETs that are, to some extent, driving and accelerating national transition processes. In order to understand the lack of strong regional participation and leadership in the transition process in the UK, it is necessary to examine regional renewable policies.

The paper addresses those broad concerns by answering the following research questions: First, why should MLP conceptualize transitions on multiple spatial scales? Second, can differences in niche development and national policy landscapes account for the relatively low renewable energy share in the UK's energy portfolio? Third, how can regional transition processes and policies complement and strengthen national transition processes? Fourth, how does the innovative potential of UK regions compare with those of other European regions? Fifth, what regional renewable energy policies are in place to stimulate deployment of and niche creation in renewable energy policies in the UK?

In order to answer these questions, section two critically reviews the MLP and highlights the theoretical importance of a multi-scalar approach to energy transitions in order to increase deployment levels and exploit local externalities for niche creation in renewable energy sources. Section three provides the empirical analysis. Utilizing secondary data and various UK government documents, the paper will first compare deployment shares, patent activity, R&D spending and incentive structures for renewable energy sources in the UK with the leading EU countries such as DK, GE and SP at the national scale revealing the importance of strong market incentives and technology push for renewable energy deployment. Second, in order to identify the capacity for regional path creation, the number of patents in RETs in UK regions is compared with those of other European regions. While national policies are clearly important, there are a number of cases where regional policy intervention resulted in strong regional clusters of renewable development and deployment that may, in some cases, accelerate development and deployment at the national scale. Third, the case of Navarra will be used to illustrate that strong economic incentives and political leadership can accelerate transition processes in the region but also influence the process at the national scale. Regional champions in RETs that could serve as showcase and influence national transition processes are currently missing in the UK. Fourth, the weaknesses of past regional policies to stimulate deployment and path creation in RETs are summarized and the potential merit of recent changes in energy, economic and spatial policies for increasing regional deployment, innovation and production of RETs in the UK are examined. Section four concludes the paper.

Conceptualizing Energy Transitions: The MLP

There are at least four approaches to research transition processes: innovation systems, MLP, complex systems and evolutionary systems (Van den Bergh *et al*., 2011). While they emphasize different theoretical concepts and prioritize different empirical characteristics of transitions, they all focus on the relationship between the creation of diversity in form of innovation and niches and selection of diversity through context-specific market, institutional, social and cultural pressures. Probably the most widely used concept to study socio-technological transitions is the MLP. The MLP builds on the systems of innovation approach, evolutionary economics and sociology of technology. The systems of innovation approach is useful for characterizing and identifying the key components and (primarily) technical relationships among existing system components, but has little to say how the system can be transformed into something else (Edquist, 1997; Coenen & Diaz Lopez, 2010). Enriching the systems of innovation approach with insights from evolutionary economics and the sociology of technology adds a dynamic component and broadens the systems perspective to include social, institutional and multi-actor networks in the analysis.

The MLP organizes analysis of transitions into a socio-technical system that consists of *niches* (micro-level), *regimes* (meso-level) and *landscapes* (macro-level) (Kemp, 1994; Rip & Kemp, 1998; Geels, 2002, 2005; Geels & Schot, 2007; Smith *et al*., 2010). The starting point for the development of the MLP was Nelson and Winter's (1977) notion of a technological regime referring to the cognitive rules and design heuristics that guide individual and firm searches for and development of innovations along specific technological trajectories. Rip and Kemp (1998) and Geels (2002) broadened the concept insisting that technological regimes are embedded in institutions and infrastructures that shape technological trajectories. Geels (2002) replaced the term technological with *socio-technical regime*. More specifically, Geels (2005) suggests that the regime consists of three interlinked dimensions: "(1) networks of actors and social groups; (2) formal, normative and cognitive rules that guide the activities of actors; (3) material and technical elements" (Verbong & Geels, 2007, p. 1026). In the UK electricity regime important actors are utilities, large industrial users, households and the Department of Energy and Climate Change (DECC) (Foxon *et al*., 2010). Formal rules include regulations, standards and laws. Cognitive rules are belief systems, problem agendas, guiding principles and search heuristics. Normative rules encompass the role of relationships and behavioural norms. Material and technical elements includes resources, grid, power generation plants and so on.

Existing social networks represent "organizational capital" that is protected and mobilized by powerful, incumbent actors to serve their interests. Regulations and standards may stabilize regimes and strong ties among actors may result in cognitive lock-in that prevent actors from searching for solutions outside the regime (e.g. for renewable energy sources, decentralized energy production, etc.). Investments are sunk in large-scale infrastructure that is protected from devaluation by its owners and network complementarities result in increasing returns, further strengthening the status quo. For these reasons, the dominant regime in general and the energy sector in particular exhibits strong path dependence and lock-in (Hughes, 1983; Grabher, 1993; Arthur, 1994; Unruh, 2000; Scrase *et al*., 2009).

As a result of lock-in, socio-technical regimes tend to produce complementary, incremental innovations that strengthen existing technological trajectories. Radical innovations that may form the technological basis for new path-breaking, socio-technical regimes are generated in *technological niches*. Radical innovations are thought to need protection because they are often expensive, less efficient and not complementary with existing socio-technical regimes. Universities, the armed forces, social networks of entrepreneurs, alternative think tanks or region-specific selection environments may provide a protective umbrella from immediate market selection. As niche innovations provide the seeds for transition, niche development needs to be nurtured, stimulated and managed. Niche expansion is dependent on a supportive institutional framework and socio-cultural environment, co-evolution of complementary technologies and the establishment of strong networks among niche and component producers and users to generate the necessary externalities to achieve economic viability and eventually superiority over regime technologies (Hekkert & Negro, 2009). Assuming that socio-technical regimes are complex adaptive systems, it is important that a portfolio of niches is maintained to obtain both, design and path flexibility (Alhemade *et al*., 2009; Stirling, 2011; Van den Bergh *et al*., 2011).

Socio-technical regimes are situated in a *socio-technical landscape* or selection environment that contains a number of heterogeneous factors such as oil prices, economic growth, wars, demographic trends, political coalitions, cultural and normative values, or environmental problems but also government regulations. Landscapes serve as external, slow-changing environments that exert pressure on regimes and niche production. Rates of economic growth influence investment patterns that in turn, influence inventive activity and/or diffusion of alternative technologies. Changes in the institutional environment influence the search for and selection of alternative sources of energy production and distribution. Regional and national governments can shift selection pressures in favour of RETs through regulatory and financial instruments such as renewable obligations (ROs) or feed-in-tariffs (FITs), public R&D funding or carbon taxes. Growing environmental awareness as part of socio-cultural development may be considered a landscape process that puts pressure on politicians, firms, organizations and opens up windows of opportunities for niche alternatives to compete with dominant technologies.

The MLP offers a relatively straightforward way to organize and simplify complex transition processes. Its conceptual framework links specific innovation activities in niches to large scale transformations at the regime and landscape levels and so mirrors the relationship between variety/path creation and selection of evolutionary theory. The detailed historical analysis of niche, regime and landscape change to explain transitions by the MLP offers a rich picture of how new socio-technical regimes rather than a single technology or sector (which is often the focus of evolutionary economics) emerge and eventually become dominant.

> The MLP argues [that] portfolios of policy measures need to work across: the destabilization [unlocking] of incumbent regimes (so that opportunities for structural change increase); the promotion of radical green niches (so that the portfolio of promising solutions broadens); and processes for translating ideas and practices from niches into mainstream settings. (Smith *et al.*, 2010, p. 445)

Despite its analytical appeal and relative success in empirical research, a number of criticisms have been launched against the MLP (Smith *et al.*, 2010). First, the relationship between niche, regime and landscape levels are far more complex than originally envisioned by the the MLP. Second, the interaction between plural regimes and niches are more complex than suggested by the MLP. Third,

> making the core concepts of niche, regime and landscape operational for empirical research is a question of bounding, partitioning and ordering the system under study. Any attempt at bounding and analyzing complex, emergent socio-technical systems will necessarily be partial, situated and temporary. (Smith *et al.*, 2010, p. 444)

Fourth, as transition researchers are attempting to actively manage the transition process, a clear understanding of existing power relations and distribution of resources among various actors is necessary. A fifth shortcoming and the most important in the context of this paper is the lack of attention to spatial scale. The MLP generally operates at the national scale because most of the regulations, institutions and policy audiences operate at that scale, but regional niche creation and landscapes may complement, speed up or even shape national transition processes.

Regionalization to Unlock National Energy Regimes

Because the majority of existing energy regimes are centralized, decentralization of energy production will result in frictions in the existing regime necessary for regime transitions to occur. Decentralization of the energy system would increase flexibility, result in locally specific energy systems challenging existing power relations and oligopolies, devalue existing infrastructure arrangements and social capital and result in a modular arrangement of energy supply and use. Devaluing infrastructures and social capital could lower profit rates of national suppliers, grid operators and generators, increase energy prices (and costs for consumers) and level the playing field opening up windows of opportunities for niche developments and force incumbents to adapt to changing circumstances.

An exclusive focus on national energy generation at the expense of regional energy regime development also under-utilizes a number of potential sources for renewable, low-carbon energy solutions such as district heating (Watson *et al.*, 2010). Learning effects from the *deployment* of region appropriate renewable energy sources are likely to stimulate the *development* of renewable energy (e.g. Danish energy cluster Fiona supporting among others, the formation of a district heating centre of knowledge[1]). Exploitation of community energy sources is vital to transform energy sectors. In this sense there is no option but to decentralize the grid (Unruh, 2000).

How regions plug into and transform the existing energy system will depend on regional characteristics. In the UK, the recently commissioned regional renewable capacity studies identify the potential of various renewable energy sources at the regional and local authority levels (DECC, 2011[2]). Locally and regionally specific solutions are necessary because locally existing infrastructure configurations such as housing, transportation, energy systems and skill sets as well as "natural" environments for energy generation vary and need to be tailored to reflect those differences. Examples include "hydrogen cities" mobilizing their relational assets and focusing on technological fixes to reduce energy use and carbon emissions (Hodson *et al.*, 2008; Hodson & Marvin, 2010) as well as rural "energy regions" developing energy visions around local resource use (e.g. biomass), energy autarky and regional energy surplus creation (Späth & Rohracher, 2010). National energy regimes can be challenged through this increasing diversity of smaller energy systems based on the deployment of different renewable energy sources, some of which will necessitate the development of smart grids.

While deployment of renewable energy systems serves regions directly through the ability to reduce energy import and generate revenue from sales of energy, regional leakages of surplus value can be reduced if actors learn from installing and using renewable energy systems and contribute themselves to niche creation.

Regional Path Creation

Unlocking the national energy system opens up the potential for developing RETs often available in green niches. If, as evolutionary economic geographers claim, knowledge spillovers are geographically constrained (Jaffe *et al.*, 1993) and innovation is a geographically localized process stimulated by spin-off dynamics, network formation and labour mobility resulting in the creation of virtuous innovative cycles (Boschma, 2009), then the regional dimension has to be developed explicitly in any successful transition to a low-carbon economy where niche innovation in "green technology" forms an essential part (HM Government, 2009).

Evolutionary economic geography is successful in explaining path-dependent development and lock-in once new niches or paths have been created, but attributes the actual path creation process to "historical accidents". This is true for the windows of locational opportunity approach (Boschma & Van der Knaap, 1997), models of path dependence (Arthur, 1994) and spin-off dynamics (Klepper, 2002). Martin (2010) proposes an alternative model of path dependence with particular emphasis on the pre-formation and path creation phase where the existing local economic and technological structures, knowledges and competences are mobilized through the purposive actions of agents resulting in the local emergence of new paths. Endogenous creation by local actors, the adoption and adaptation of novel extra-regional knowledge through FDI or firm-internal knowledge pipelines and the recombination of existing knowledge bases may result in new path creation (Martin & Sunley, 2006; Neffke *et al*., 2011). Changes may also be triggered by strong selection (landscape) pressures (such as new environmental regulations) that reshuffle national and local efficiency hierarchies (Essletzbichler & Rigby, 2007).

The application of niche innovations is often outside the core, suggesting that the opening of a technological window of opportunity may be coupled with local path creation. Niche development could thus be combined with regional development in non-core regions (Scott, 1988; Storper & Walker, 1989; Boschma & van der Knaap, 1997). Regional path creation based on clean energy technology will not only enhance national competitiveness of the industry but is also likely to benefit the regions. Clean energy technology has long-term market potential because it requires the complete reconfiguration of existing energy systems and is likely to deliver jobs, skills and revenues that benefit the local economy (Innovas, 2009).

A successful transition requires the enrolment of heterogeneous actors to sign up to a common vision in order to secure cooperation, strengthen cluster development and increase the effectiveness of transition policies. These visions will differ by place and are thus easier to develop if they build on needs of actors and availability of resources in those places.

Recent work on transition research highlights the importance of "soft" social and cultural factors to trigger and develop transition pathways (Smith *et al*., 2005). Späth and Rohracher (2010) demonstrate how sustainable Austrian "energy regions" can serve as "discursive niches" of transitions to sustainable low-carbon energy systems. In the case of the "energy region Murau", a rural area consisting of about ten municipalities, the key objectives were energy autonomy, export of energy carriers resulting in economic surplus and a high level of public awareness concerning the need for an energetic circular flow economy. Linking environmental sustainability to economic development was important in order to enrol strategic actors, such as businesses, in the alliance. Emphasis was put on potential for value creation by bringing regional resources into use with biomass being the obvious choice. Workshops and subgroups of actors developed concrete objectives focusing on issues such as wood-fired district heating systems, solar heating systems for private homes, projects for renewable electricity production and ways to improve the energy efficiency of buildings. Frequent meetings facilitated the realization of various concrete projects and significantly reduced transaction costs. Changes in planning laws, development of specific technologies (e.g. new truck design to deliver wood chips), coordinated R&D efforts, logistical infrastructure (biomass bourse) and services resulted in improvement of technical solutions and business strategies that could be exported to other regions. There was significant support from the meso-level for this project but the success story was then also employed as "proof of principle" to initiate transformations in other places and at a higher spatial scales. The example demonstrated that "energy solutions" can operate at any scale and any type of region and that successful solutions can be exchanged, adapted, diffused and probably scaled up to actively transform the national energy regime.

Landscape Pressures

A spatial focus on energy production and consumption could alter the selection pressures if regions are allowed to manipulate their selection environments (i.e. R&D policies, sustainable energy and low-carbon mandates, different tax and incentive structures). Regional institutional umbrellas could preserve inter-regional variety in niche development and thus maintain higher levels of diversity at the niche level. A spatial focus would also take into consideration the locally or regionally existing resource and infrastructure, firm, knowledge and skills bases (Martin, 2010).

Landscapes exert various pressures on regimes, regime components and niches and could be conceptualized as multiple selection environments operating on various spatial scales (Essletzbichler, 2012). Regions are subject to national landscape pressures while regional regimes are also subject to regional selection pressures. There are different ways for national governments to alter the selection environment and exert pressure on regions. Taking into account the results from capacity studies, emission budgets could be devolved to regions or local authority level. Regions successful in generating a large share of renewable energy would then be able to trade carbon permits with regions that are unable to do so. The policies may lead to transfer payments from cities to rural areas, the attraction of "green" industries and services with low-carbon footprints or the "greening" of existing industries. Revenues can then be reinvested to strengthen regional niche developments (as in the case of Southampton's geothermal energy generation project).

Regional landscapes can be designed to redistribute resources from high-carbon to low-carbon industries and firms within the region, that is, regions would have the ability to alter the price structure facing businesses and industries to push them in directions that mesh with regional environmental objectives. Regional selection environments can be designed around normative goals to influence consumer behaviour, which in turn, will influence firm behaviour. Tradeoffs among various energy saving and renewable energy generation projects can then be negotiated influencing the regional transition pathways.

If we accept the premise that attention to scale is important for the development of transition policies because regions exploit niche markets (such as medium-sized wind farms, district heating systems, energy conservation programmes, land-use planning changes) that are excluded by the incumbent regime, diversity in niche production can result in cross-regional learning as well as upward and downward scaling of existing regime structures to enhance renewable capacity generation and deployment. Hence, the transition model needs to take spatial scale into account explicitly. A visual representation of a multi-scalar, multi-level transition approach is depicted in Figure 1.

The key message here is not that regions function as independent regimes or that the regional scale is more important than the national scale but that regions, if properly endowed with regulatory authority and monetary means, contribute to the creation and maintenance of diversity in the niche practices and discourses that influence regional regimes that may or may not be scaled up, replace, interact, transform or be taken over by national regimes or other "fitter" regional regimes. Because regions differ in terms of their infrastructure, natural resource endowments, social and cultural capital, region-specific transition governance is not only desirable but necessary to improve the probability of success to a transition to a low-carbon economy. This reasoning opens up the possibility of multi-scalar transition research where transition processes at the regional scale co-evolve with processes at the national scale.

While the theoretical discussion suggests an important role for regions to develop niches and accelerate transitions at the national scale, the translation of theoretical categories such as niche, regime and landscape into empirical categories is imperfect (Smith *et al.*,

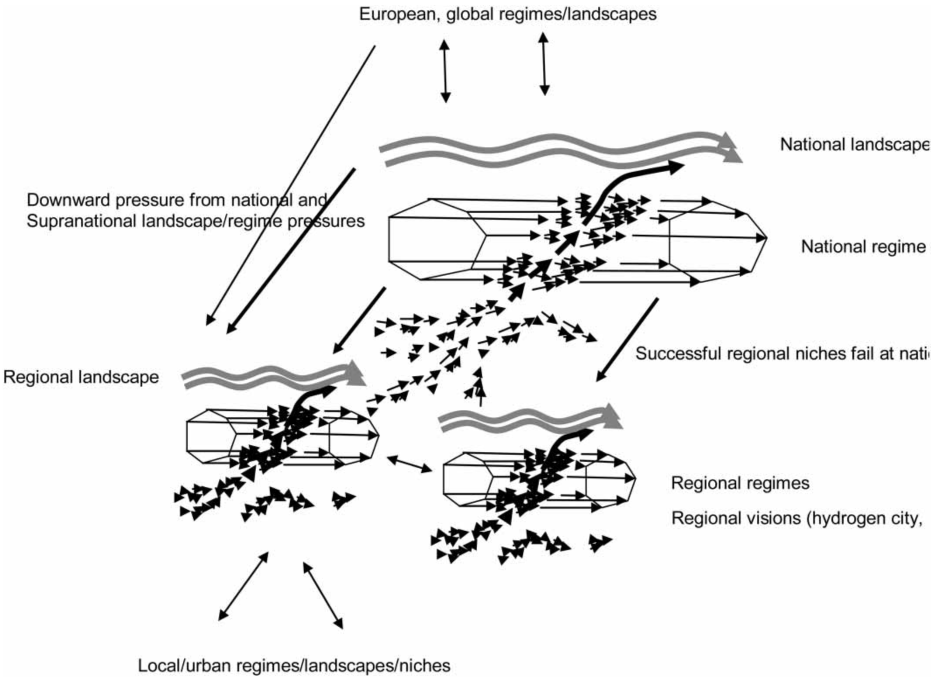

Figure 1. Multi-scalar MLP.
Source: Based on Geels (2002).

2010). In this paper, the potential for niche creation in RETs is approximated with patent data at the regional and national scale while the relative success of moving to a sustainable energy regime can be approximated by the share of renewable energy on gross energy and/or electricity consumption. Landscape pressures expected to impact the deployment and creation of RETs are defined narrowly as R&D policies and spending, investment, price and tax incentives as well as regional and local planning guidelines. In order to gain a better understanding of key factors driving energy transitions, the UK is compared to the relatively successful countries of DK, GE and SP[3].

In order to answer the research questions posed in the introduction and get an overview of the key differences and similarities of innovation and deployment in renewable energy between those countries, the following empirical part will first compare deployment shares, patent activity, R&D spending and incentive structures at the national scale. Second, patents in RETs of EU regions are mapped and relative strengths and weaknesses of UK regions summarized. The case of Navarra is discussed in greater detail because it demonstrates how regions can take the initiative and influence national transition processes. Third, existing regional policies to develop and deploy renewable energy sectors in the UK are summarized and the potential impact of current changes to energy and spatial policies on the transition process discussed briefly.

Empirical Analysis

The empirical analysis is based on secondary data sources, including patent data from the OECD, R&D expenditure data and information on incentive and tax policies as well as legislation regarding RETs from the International Energy Agency (IEA), and information on deployment levels from Eurostat. Unfortunately, official industry and export statistics could not be used as they do not discriminate between renewable energy and fossil-fuel technologies. The UK regional renewable policy is based on various government documents. A brief discussion of the data sources follows next.

Data

Eurostat[4] provides various indicators on the shares of renewable energy. For this paper, the share of renewable energy on total gross energy and total gross electricity consumption was used to get an indication of the success of national energy transition processes (Figure 2).

Patent data are generally interpreted as proxy for inventive output and innovative input (OECD, 2009). At the national scale, OECD[5] provides patent data for a number of environment-related patents while "renewable energy" patents at the TL3[6] regional level are not disaggregated further. Following the advice of OECD (2009), this analysis uses Patent Cooperation Treaty applications at the international phase (to control in part for home bias of applicants), priority year (to count patents close to the date of invention), fractional counts and allocates patents to countries/regions based on the location of the inventor rather than the applicant. This is sensible because the location of the inventor reflects where research is actually taking place rather than where the applicant (often a company) is headquartered. Patent data are not without problems. They include applications rather than actually granted patents, they do not distinguish between the relevance of applications and often contain several, non-hierarchical patent codes. If there are several renewable energy codes on the application, then the patent may be counted more than once.

Invention and innovation will depend in part on technology push and in part on market pull factors. In order to gain an idea of how strong national government support research in RETs, renewable energy R&D data from the IEA are employed. Only public R&D expenditures are included, which may bias results in favour of those countries with nationalized energy regimes. Because energy produced from renewable sources (with the exception of onshore wind) tends to be more costly than conventional energy sources (DECC, 2011), incentives need to be provided to increase deployment and potentially innovation in RETs. Data on different incentive, tax and regulatory systems are also provided by the IEA and Haas *et al*. (2011) and will be used to compare differences in national policy frameworks.

And finally, in order to examine the role of current and future regional polices to support the energy transition in the UK, various UK government documents from the DECC, the Department of Business, Innovation and Skills (BIS) and the Department for Communities and Local Government as well as various regional development agencies (RDAs) are used.

National Scale

To set the scene, Figure 2 depicts the renewable shares in gross energy (Figure 2(a)) and electricity (Figure 2(b)) consumption in the four countries and the EU-27 average. The 2009 renewables' share on gross energy consumption for EU-27, DK, GE, SP and the UK were 9.0%, 16.7%, 8.5%, 9.3% and 3.0%, respectively. Their renewables' shares in electricity con-

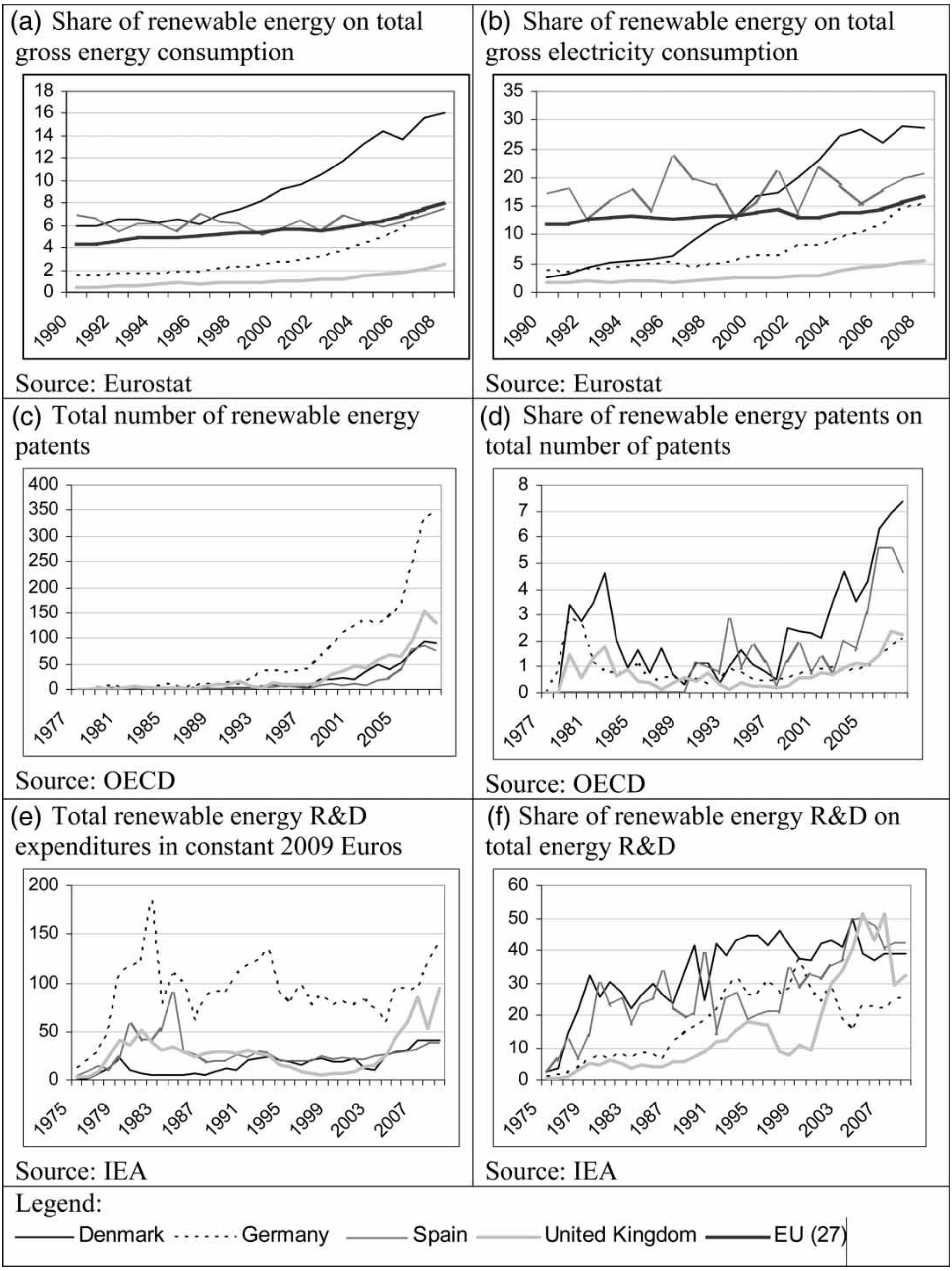

Figure 2. Deployment, patents and R&D trends for DK, GE, SP and UK.
Source: Compiled from Haas *et al*. (2011) and IEA (2011).

sumption in 2008 were 16.7%, 28.7%, 15.4%, 20.6% and 5.6%, respectively. Figure 2 reveals that the UK is far behind the leading EU countries but even behind the EU-27 average in achieving a transition from a fossil-fuel-based to a renewable energy system.

In order to get a better understanding of the relative failure of the transition process in the UK, it is useful to compare innovation in and the regulatory structure guiding renewable energy sources in the UK with the experiences of the relatively successful countries such as DK, GE and SP. According to the MLP, we need to identify green niche development and landscape pressures that may facilitate or impede the creation and diffusion of those niches. Drivers at the national scale are examined first. Figure 2(c) plots the number of patents in all RETs from 1976 to 2008. The number of patents in this sector remained relatively low until the early 1990s. GE has the highest number of patents while DK and SP emerge as leading countries in RETs once we standardize by the total number of patents (Figure 2(d)).

Table 1 presents the cumulative number of patents and the revealed technological advantage (RTA) for each of the renewable energy sectors for the period 2000–2008. RTA measures the share of renewable patents on the total number of patents in a country divided by the share of renewable patents in all countries on the total number of patents in all countries and is often considered as an indicator of comparative innovative advantage of a country in a particular technology sector. An RTA > 1 means that a country patents more in this sector than would be expected based on its total number of patents. DK's strong performance and concentration in the wind power sector is confirmed by an RTA of 14.1. GE holds the largest amount of patents in all renewable energy sectors save for marine and tidal/wave technology although its RTAs tend to be smaller than in other countries because of its large number of total patents. SP is now holding significant numbers of patents in wind, solar thermal, solar photovoltaic (PV) and wave technologies. The UK has a comparative advantage in marine and wave/tidal technologies and also improved its position in the wind power sector (possibly due to its competitive position in offshore wind).

Inventive output is driven in part by R&D expenditures and in part by market expansion. Figure 2(e) traces the evolution of public R&D in renewable energy sectors. After fast increases in R&D budgets as a reaction to high energy prices in the 1970s, R&D expenditures dropped during the recession of the early 1980s. GE had the highest R&D budget, while those of the UK, SP and DK were relatively similar for most of the period despite the UK economy's size (see Jamasb *et al.* (2008) on UK's R&D policy). DK and SP started

Table 1. Patents, shares and RTA for DK, GE, SP and the UK.

	DK			GE			SP			UK		
Energy source	Patents	Share	RTA	Patents	Share	RTA	Patents	Share	RTA	Patents	Share	RTA
Renew. all	401.6		3.9	1486.1		1.0	308.4		3.0	584.3		1.0
Wind	341.4	81.1	14.7	497.1	29.6	1.5	134.8	38.5	5.7	167.1	24.6	1.3
Solar thermal	26.0	6.5	1.7	274.3	16.3	1.3	102.1	29.1	6.8	65.5	9.6	0.8
Solar PV	9.1	2.3	0.2	698.3	41.5	1.1	61.3	17.5	1.3	232.5	34.2	0.9
Solar hybrid	1.0	0.2	0.7	32.3	1.9	1.6	4.0	1.1	2.7	5.7	0.8	0.7
Geothermal	3.0	0.7	1.3	47.0	2.8	1.4	2.0	0.6	0.8	9.5	1.4	0.7
Marine (excl. tidal)	20.5	5.1	4.6	20.9	1.2	0.3	23.0	6.6	5.1	76.9	11.3	3.2
Tidal, stream	5.2	1.3	1.4	31.8	1.9	0.6	7.0	2.0	1.9	72.2	10.6	3.6

Source: OECD Patent Statistics.

investing substantial shares of their energy R&D budgets in renewables in the late 1970s and early 1980s (about 40% of their total budgets) (Figure 2(d)). DK focused its resources on wind and bio-energy early on, while SP diversified its investment portfolio into geothermal (until the late 1980s), bio- and solar energy with wind playing only a minor role until the late 1990s (Klaasen *et al*., 2003). GE's renewable R&D shares started to increase in the late 1980s with PV and, since the mid-1990s, wind being the main beneficiaries. The UK was characterized by a low percentage of renewable R&D on total energy R&D until the 2000s despite early investment in ocean and geothermal energy research. The UK's renewable share on total energy R&D was less than 10% until the 1990s and less than 20% until 2000 when it started to climb to 50% in 2006. The recent increases in R&D expenditures are primarily due to an increase of R&D investment in the PV sector but may also reflect commitment to offshore technologies. Econometric analyses show that public R&D expenditures have a positive and statistically significant effect for patenting activity in the wind and solar energy sector (Johnstone *et al*., 2010) while work on the relative effects of induced technological change and policy-induced substitution suggest that the latter is more important for generating investment in renewable technologies (Hascic *et al*., 2010).

While R&D and patenting activity in the UK appeared relatively low compared to the other three countries, the renewable deployment gap is even wider. It is thus necessary to look at the evolution of the incentive and regulatory landscape in those countries to understand how diffusion of niche technologies has been accomplished. Figure 3 summarizes the main policy changes affecting research in and deployment of RETs including investment incentives, tax credits, low interest/soft loans, tendering systems for investment

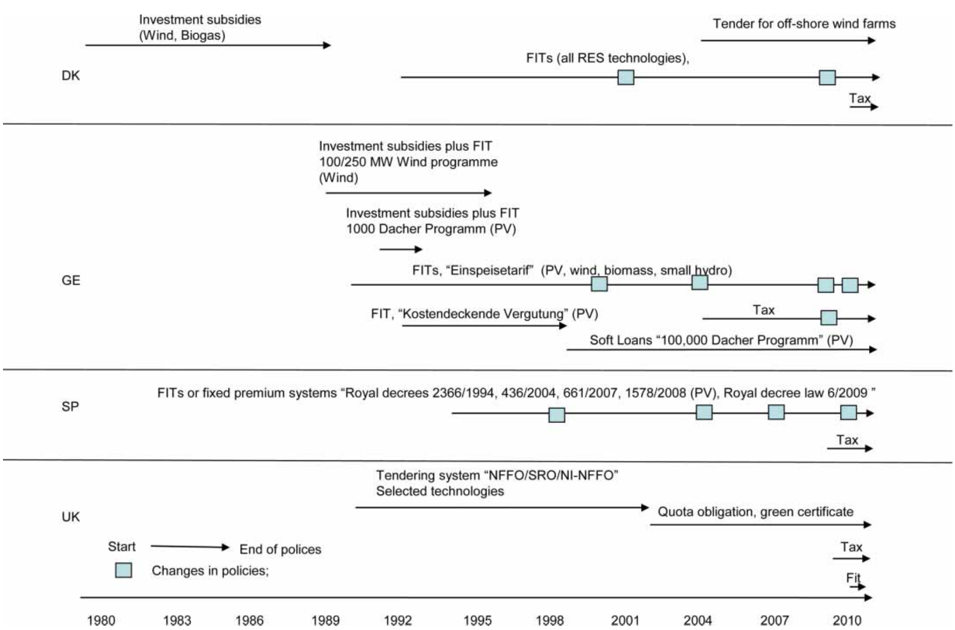

Figure 3. Key policies with respect to renewable energy in Denmark, Germany, Spain and UK.
Sources: Compiled from Haas *et al*. (2011) and IEA (2011).

grants, FITs and fixed premium systems, tendering systems for long-term contracts and tradeable green certificate systems (for a summary of the various instruments, see Haas *et al*., 2011).

Wind energy was promoted in DK since the 1970s through a mixture of investment subsidies, tax refunds, R&D support and, since the 1990s, FITs (Klaasen *et al*., 2003). Up to the 1990s, the main owners of wind turbines were cooperatives resulting in high deployment rates and low objections to planning applications (Munksgaard & Morthorst, 2008; Haas *et al*., 2011). The careful timing between R&D support, investment incentives and procurement support played an important role in the success of the Danish wind industry with Vestas dominating the global market for wind turbines (REN21, 2011) and the Aarhus–Aalborg cluster attracting Siemens, Suzlon and Gamesa to DK (Cooke, 2010). GE has encouraged the use of wind energy since the 1970s through the use of FITs and tax breaks, resulting in a rapid diffusion of wind power (Klaasen *et al*., 2003), while the rapid increase in solar PV was supported through investment subsidies, low interest loans and FITs. The Spanish renewable energy sector benefited primarily from generous FITs that resulted in rapid deployment of wind and more recently PV. SP has the second largest installed wind capacity and second largest PV capacity and is the largest solar thermal electricity producer in Europe. The regulatory framework provided stability for developers to recover costs necessary for the rapid deployment of those sources (IDAE, 2010). In contrast to the above three countries, the UK relied primarily on tendering, green certificates and ROs. The tendering system and ROs were useful for obtaining low support prices but only the best, most competitive locations were viable while renewable energy targets were never met (Haas *et al*., 2011). As a result of those policies, the UK lags far behind the European leaders in renewable energy generation and innovation.

This is now recognized and a number of recent changes to promote renewable energy in the UK have been introduced. The most important change affecting the renewable energy sector is the introduction of an FIT system to complement and eventually replace the RO system (DECC, 2011). Since then, 164 MW of capacity was installed, of which 121.6 MW are small-scale solar PV installations (DECC, 2010). Unfortunately, the first review of the FIT took place in February 2011, causing uncertainty and instability in the market. The implementation of FITs is complemented by investment in the grid to accommodate variable power sources such as wind and solar energy but also to connect offshore wind farms to the onshore grid, the green deal to improve building efficiency, the micro-generation strategy and, as overarching strategy, the "renewable energy roadmap" (DECC, 2011) that sets out various strategies to increase deployment of renewable resources and implementation is supported by the six National Policy Statements (NPS) for Energy that highlight the need to increase deployment rates for renewables and provides guidelines for planning decisions on large energy infrastructure projects. The "energy roadmap" recognizes offshore wind and marine energy as technologies to be exploited by UK industry. While rising R&D in renewable energy, strong competitive advantages in offshore (wave, tidal and wind) technologies (Halliday & Ruddell, 2010; Jay & Jeffrey, 2010) and part of the PV value chain (Irvine, 2010) and positive regulatory changes show some encouraging signs already, sub-national industrial and energy policies could aid the transition process for at least four reasons: First, evolutionary economic theory emphasizes the importance of spillovers for niche creation and technological change. Second, regions, cities and localities can take advantage of "first nature" geographies and specialized resources such as firm or research networks. Third, as renewable energy projects need to be implemented at the local scale consent for them is easier to obtain if communities and local authorities are included in project design and realize returns from it. Engagement with localities may thus reduce planning delays and rejections, which constitute one of the major bottlenecks for wind farm and biomass deployment in the UK (BWEA, 2010). Fourth, energy policies have neglected meso-level, decentralized solutions (e.g. district heating) and focused on the international, national and building scales with little regard for the potentially vital role of regions, cities and localities to develop alternative, locally adapted energy scenarios (Scrase *et al.*, 2009; Watson *et al.*, 2010).

Regional Scale

In order to offer an indicator of the regional potential for niche development in the renewable energy sector, Figure 4 maps the total number of patents for the European TL3 regions between 2006 and 2008 (the last year for which data are available). Thus, the information represents current inventive capacity.

Echoing the performance at the national scale, the dominance of Danish regions and a selected number of Spanish and German regions in renewable energy patents is clearly visible, echoing the strength of these countries in the renewable energy sector. Of the top 10 patenting regions, 3 are Danish, 5 are German, 1 is Spanish and 1 is Dutch with Eastern Jutland (DK) producing by far the largest amounts of patents (91.2) followed by Munich (GE) with 56.2 and Südlicher Oberrhein (GE) with 51. While the UK as a whole is among the top 10 of renewable energy patent producers, only Cambridge and Cardiff produced more than 20 patents over the last 3 years. While Cambridge applied

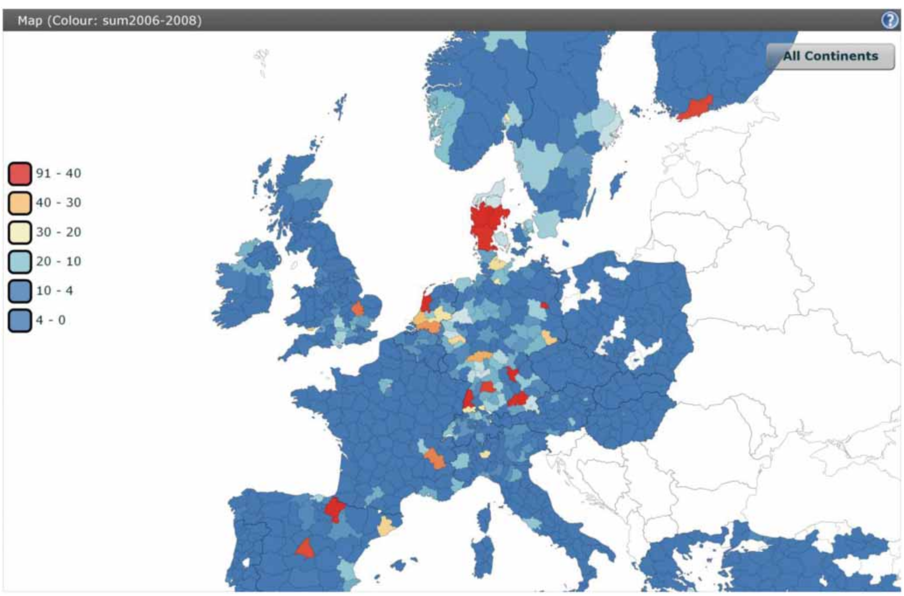

Figure 4. Cumulative number of renewable energy patents (2006–2008) for TL3 regions. *Source*: OECD; mapped with OECD eXplorer.

for patents on a regular basis, the high number for Cardiff is due to a unique high value in 2007. When aggregating all five London TL3s, London has the same patent count as Cambridge (35). Other important regions in the UK are Southampton, Hampshire and Oxfordshire. Once we account for population size (and eliminate regions with less than or equal to six patents in those 3 years) Cambridge, Southampton, Cardiff and the Isle of Wight are all among the top 10, while all German regions but Südlicher Oberrhein drop out (Table 2). Three Danish regions and Navarra remain in the top 10 complemented by Neuchatel (CH). If we calculate the share of renewable energy patents on the total number of patents in order to obtain a relative performance measure, Southampton, Cardiff and the Isle of Wight remain in the top ten together with various North German and Danish regions as well as Navarra and Almeria (ES) (Table 2). While the German, Danish, a number of Spanish and Dutch regions dominate patent counts in RETs in absolute terms, a number of English regions perform well once we control for population size or total patent activity in a region. The Danish regions and Navarra remain among the top in absolute and relative terms, while Northern and some East German regions perform well even after controlling by the total number of patents.

While national policies are probably the main drivers for the development of strong renewable energy sectors and spatial clusters of economic activity, regional industrial policies were employed to attract the PV industry to the depressed economic areas of East GE, Saxony, Thuringia, Saxony-Anhalt and Berlin-Brandenburg explaining the high patent counts in Berlin and Oberes Elbtal/Osterzgebirge (including Dresden) (El-Beyrouty *et al*., 2009; GTAI, 2009). The dominance of Danish regions (especially Jutland) in the wind power sector was the result of strong deployment incentives combined with carefully targeted industrial policies as well as community ownership of wind farms in the 1980s when the industry took off (Munksgaard & Morthorst, 2008; Cooke, 2010). In the following, the case of Navarra is discussed in greater detail as it demonstrates the importance of incentive policies to increase regional deployment attracting investors and R&D facilities

Table 2. Regional RET patenting activity.

RET Patents per 100,000 inhabitants		Percentage of RET patents on total patents	
TL3 region	RET Patents/ 100,000 pop.	TL3 region	RET Patents/total patents
Vestjylland	38.3	Ostfriesland	25.6
Østjylland	37.6	Navarra	25.0
Southampton	27.5	Vestjylland	19.4
Navarra	23.4	Østjylland	18.7
Cardiff and Vale of Glamorgan	20.6	Schleswig-Holstein Nord	18.2
Isle of Wight	20.3	Almería	18.0
Cambridgeshire CC	19.7	Cardiff and Vale of Glamorgan	17.4
Sydjylland	18.6	Isle of Wight	15.8
Neuchâtel	17.9	Southampton	11.9
Südlicher Oberrhein	16.3	Schleswig-Holstein Mitte	11.2

Source: OECD Patent Statistics.

to take advantage of spillover and learning effects, which in turn help to accelerate deployment and development of RETs at the national scale.

The development of the wind power cluster (and to a lesser extent the solar industry) in Navarra is the result of resource scarcity in the region, strong government incentives and entrepreneurial talent. As early as 1985, the regional government passed a law to diversify its energy sources, reduce energy dependency and use abundant renewable energy sources, increase energy efficiency and develop new infrastructure for those RETs (Faulin *et al.*, 2006). To support this endeavour, Energia Hidroelectrica the Navarre (EHN) was founded in 1989 by Esteban Morrás supported by capital from the regional government, its dependent savings bank and the regional utility company Iberdrola. The company was set up with the explicit goal to increase the renewable energy share in the region (De Miguel Ichaso, 2000; Fairless, 2007; Gobierno de Navarra, 2010). Confronted with the physical limits to expand the network of small hydroelectric power plants in the region, Morrás turned to Vestas (a Danish company and global leader of wind turbine production) and discussed an ambitious plan for wind power deployment in the region and SP in general. The first turbines were installed in 1994. From 1993 onwards, EHN was in the business primarily to develop aero-generators and wind farm development and in 1994, Gamesa Eólica was founded as a joint venture between EHN, the regional government and Vestas to supply wind turbines to EHN.

The turn to wind as a major power source was supported by the regional government in three ways: First, the government set itself ambitious targets in its 1995/2000 energy plan that it surpassed; Second, in addition to the national FIT, the regional government offered generous investment subsidies to private companies (20% of investment costs between 1994 and 1999 and 30% of investment costs between 2000 and 2004; Faulin *et al.*, 2006) in addition to support for the construction of renewable energy installations (wind farms, solar parks, etc.) totalling €400 million by 2004. Third, local authorities subscribed to the regional plan and public consensus was the result of recognition of the need for wind energy as primary energy source and payments from developers and the local government for the use of land for RET and development of land around installations. As a result, wind capacity was deployed much faster in Navarra than in SP over the period 1995–2004 (Figure 5(a)). Between 1998 and 2000, Navarra's share on SP's installed wind capacity exceeded 20% (while accounting for only 2.5% of total land mass) and in 1996 and 1998 more than a quarter of newly installed capacity was deployed in Navarra (Figure 5(b)).

In addition to providing 65% of total electricity consumption in Navarra, the wind boom attracted a number of key companies to the area including Acciona, the world largest wind farm developer, taking over EHN in 2004, Gamesa Eólica (now among the top three global wind turbine manufacturers), Alstom Power (Ecotechnica) and MTorres (Gobierno de Navarra, 2010). As a result, 14% of the world's aero-generators were produced in Navarra in 2000 (Faulin *et al.*, 2006). Overall, there are more than 100 RET companies employing over 5000 workers in the region. Complementing the strong private sector are the Technological Centre of Renewable Energy Sources that was established in 2002 and the Integrated National Centre for Training in Renewables that was established in 2003, making Pamplona the *de facto* renewable energy centre of SP. Because of its strong institutional support, Navarra was awarded the EU prize for best regional renewable policy in 2004 and attracted considerable attention from political delegations within and outside SP. In this sense, Navarra becomes a showcase for the design of renewable

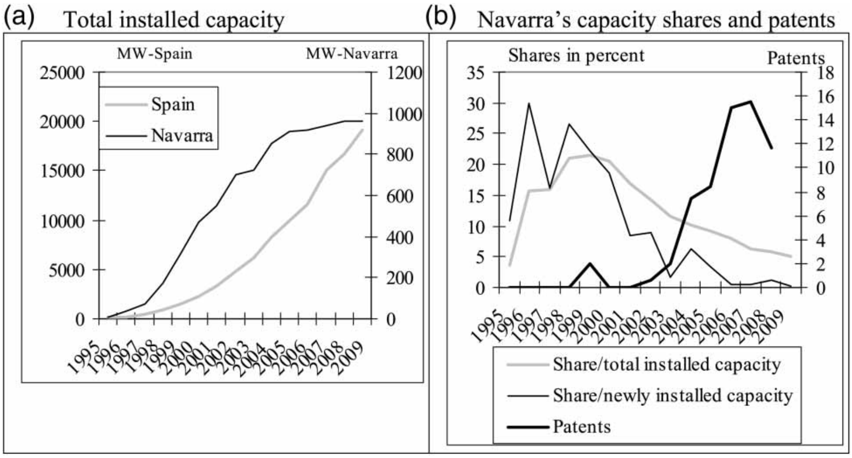

Figure 5. Wind energy deployment in Navarra and SP, 1995–2009.
Source: IDEA (various year): Wind energy in Spain, current status reports.

energy policy that can be reproduced (probably in modified form) somewhere else. While Navarra constitutes only a single case, a number of insights can be gained: First, strong incentive policies at the national scale are necessary for increasing renewable deployment levels. Second, renewable shares can be increased significantly through additional support at the regional scale. Third, deployment leads to R&D, patent activity (Figure 5(b)) and production. Companies and research facilities follow the markets and good institutional support structures (at least in the case of onshore wind since the late 1990s). Fourth, the formation of regional clusters is important as they can become drivers of national competitiveness in the industry. Fifth, strong local incentives and realization of local benefits increase the acceptance of RETs allowing rapid deployment in the first place. Sixth, and complementing the Navarra case study, the regional patent analysis revealed that the relatively successful energy transitions of DK, GE and SP are linked to strong regional patenting activity. For these reasons, attention to the sub-national scale can aid our understanding of energy transitions in general.

Returning to the UK, the large number of patents in Cambridge is not translated into renewable clusters or higher deployment levels in the area or wider UK. The neglect of and need for the development of a green energy technology cluster is explicitly mentioned in Library House's (2007) Cambridge cluster report. However, relatively high patent numbers in Cambridge, London, Oxford and Southampton/Hampshire do indicate inventive activity that could form seeds for regional path creation in RETs. As the case of Navarra and East GE indicated, strong patent performance was led by investment and deployment incentives to translate inventions into viable products and generate regional clusters of specialized economic activity that can then increase national competitiveness in the industry. The UK renewable energy policy tends to be technology-specific and not region-specific, although offshore technologies do generally favour coastal areas with port facilities (DECC, 2011). The following section briefly reviews regional renewable energy policies in the UK and evaluates the potential impact of recent changes in energy and spatial policies to develop industrial clusters and accelerate the UK's energy transition.

Regional Renewable Policies in the UK

While the national government is responsible for promoting technology development and providing deployment incentives, the local level is where new projects are implemented and where formal and informal consent to local projects is given. Situated between the local and the national scale, was the regional scale with government offices (GOs) (set up in 1994), RDAs and regional assemblies (RAs) (set up in 1999), regional stake holders and national organizations with regional operations (such as the Carbon Trust or the Energy Savings trust) charged with devising regional renewable targets, regional spatial strategies favourable to renewable energy, setting up regional R&D centres and energy agencies, and facilitating the development of clusters and supply chains all in the context of increasing regional economic performance. Regions were supposed to operate strategically as they had knowledge of the situation on the ground as well as policy frameworks at the national scale. GOs, RDAs and RAs were the key regional governance bodies devising strategies and implementing them (Smith, 2007; CLG, 2009).

By 2004/2005, GOs administered £9 billion of central government expenditures, employed over 3000 civil servants and coordinated regional renewable energy partnerships (CLG, 2009). RDAs invested £2.2 billion each year into regeneration and were the key source of regional funding for renewable energy. RAs included renewable energy provisions in spatial and housing strategies, providing the key driver for boosting regional capacity in renewable energy (Smith, 2007). The Department of Trade and Industry (DTI) provided each region with £100,000 for facilitating renewable energy governance, partnership building and consultation processes, conducting renewable energy resource assessments and establishing regional targets.[7] Regional targets were developed pragmatically based on regionally available resources, planned housing expansion, businesses already in the region and so forth. While formal governance structures existed, they were endowed with too little financial and administrative support (e.g. regional targets were not binding) to have a major impact on regional renewable deployment in the UK. Other problems to implement renewable energy policy identified by the RAs were (among others):

> Funding uncertainties; inconsistency in obtaining planning permission for wind developments and the way regional planning policies are applied by local authorities; concern over the use of cumulative effects of anecdotal evidence (including unevidenced impact on bird populations) against granting planning permission for further wind farm developments; lack of sufficient local public benefits or securing these consistently to act as an incentive to implementing renewable energy developments and projects; lack of political will and leadership to push through large scale development projects in the face of local opposition. (CLG, 2009, pp. 29–30)

As a result, regional targets were not met. Figure 6 compares deployed renewable capacity in the English regions in 2009 with the 2010 and 2020 regional renewable targets. Judged solely by deployment/target ratios, regional renewable policies have failed. In 2009, only London surpassed its renewable energy target of 2010, while the Southwest and Yorkshire and Humber had installed less than a third of the 2010 target.

While formal regional governance was insufficiently supported, the seed money of the DTI led to the emergence of informal networks. The main tasks were the identification,

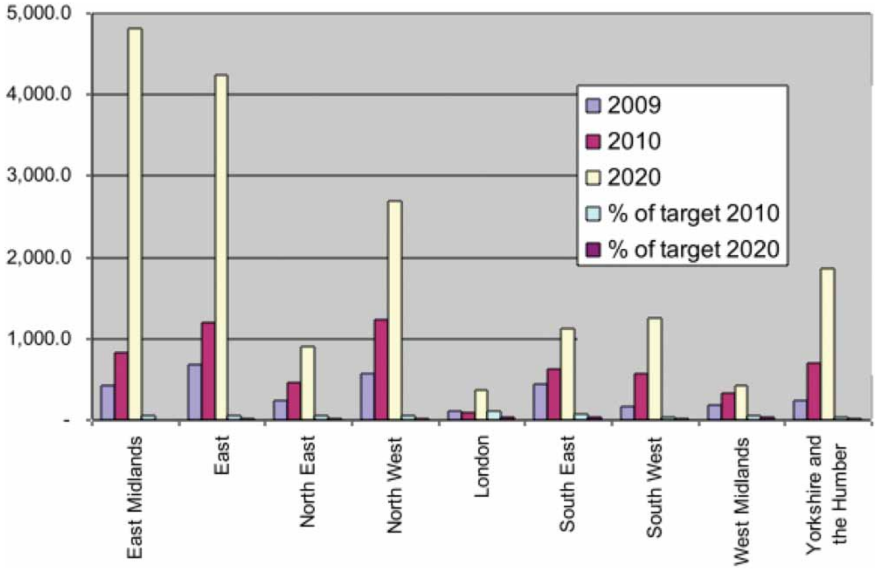

Figure 6. Installed renewable capacity 2009 and target capacities for 2010 and 2020 for nine English regions.
Source: 2009 Capacities: DECC Regional Renewable Statistics; 2010 and 2020 targets from CLG 2009, Table 4.3.
Note: Targets for London, Northeast and West Midlands reflect on-shore targets only.

communication and promotion of the regional energy business potential, the mapping of renewable energy business clusters and support of them, analysis of regional renewable energy supply chains and securing contracts for local firms from entering renewable businesses, creating renewable R&D facilities, assessing skill needs and providing training programmes, and providing tools and services for local businesses to access national and European funding bodies (Smith, 2007). All regions have tried to measure and map existing renewable energy business in their region. For instance, the Northwest RDA estimates that the regional energy and environmental technology sector employs more than 50,000 people (25,000 in the nuclear industry) and over 100 renewable energy companies in the wind and tidal sectors[8] while envirolink Northwest identifies 353 suppliers for renewable energy and 15 research groups in seven universities in the Northwest[9]. Similar exercises took place in all other regions and created a wealth of knowledge and networks with the potential for building stronger renewable energy industries in the regions. Another important step to increasing deployment was regional renewable capacity studies commissioned by DECC (see Note 2) with the intention of regions and local authorities to act on this information, perhaps through development of common, local energy visions around local "first nature" advantages.

The creation of informal networks and formal renewable energy groups (e.g. Southwest region) also resulted in lobbying at the national level in order to help attract international renewable energy capital highlighting the complex relationship between energy policies at the national and regional scales. In the case of the Southwest, the RDA contributed £2 million to a £15 million project to establish a "Wave Hub"off the Cornish coast. In order to enrol DTI support for Wave Hub[10], Southwest region had to organize a national conference on the finance and policy issues surrounding marine technologies. While wave hub was not the only institution pushing for wave technology, the combined power of regional projects and early research outcomes have convinced DECC to continue funding marine energy projects. DECC, the Carbon Trust and BIS now recognize wave and tidal technology as one where the UK has a competitive economic advantage (see also Table 1). The Carbon Trust (2011) estimates a total cumulative market of close to £350 billion peaking in 2040 with £6 billion. As the market leader in marine technologies, the UK should be able to capture a significant part of the potential revenues and the investment to bring the technology to the market seems justified. DECC supports marine energy technology with £20 million over the next 4 years (DECC, 2011) and will establish a marine device testing facility at Narec (the national centre to advance renewable energy) while BIS announced a Technology and Innovation Centre with a focus on offshore renewable energy including offshore wind, wave and tidal technologies.[11] While offshore wind technology has been deployed commercially, wave and tidal technology is still in the development stage with a variety of designs being tested at the moment to maintain diversity and avoid lock-in to inferior technological trajectories (Arthur, 1994; Stirling, 2011). In addition to wave and tidal technologies, offshore wind power requires excellent port facilities, expertise in installation of offshore wind towers and offshore grid connection where the UK does have a strong competitive advantage through its expertise in North Sea oil and gas drilling (Jay & Jeffrey, 2010). The UK also benefits from "first-nature" advantages in these technologies, making it attractive to foreign investors to take advantage of those resources. All three eastern regions – Northeast, Yorkshire and Humber, East of England – develop strategies to take advantage of the coming "offshore boom".

According to the CLG (2009), RDAs, RAs and GOs were among the key players in developing and implementing national renewable policies through embedding renewable energy targets in regional spatial strategies and regional economic development plans. However, regional strategies and RDAs will be abolished and local authorities and Local Enterprise Partnerships (LEPs) are supposed to take over. In a letter[12] to the chief planning officers (dated 6 July 2010) revoking the regional spatial strategies, the chief planner stated that

> Through their local plans, authorities should contribute to the move to a low carbon economy, cut greenhouse gas emissions, help secure more renewable and low carbon energy to meet national targets, and to adapt to the impacts arising from climate change. In doing so, planning authorities may find it useful to draw on data that was collected by the Regional Local Authority Leaders' Boards (which will be made available) and more recent work, including assessments of the potential for renewable and low carbon energy.

The capacity studies commissioned by the regions do contain information at the level of local authorities that could be used to design local energy visions around existing resources. Inclusion and support is easier to obtain at the local level if people, businesses and policy makers can rally around common goals and engage in the design and implementation of local and transition pathways that gel with local endowments and result in benefits for local communities through job creation and revenues from energy sales (Scrase *et al*., 2009). In response to calls for exploitation of meso-level renewable sources (Watson *et al.*, 2010) and the need to incentivize renewable deployment for local communities, new legislation allows local authorities to develop their own renewable energy sources and keep the profits for reinvestment in their communities (Huhne, 2010). A sense of ownership by communities may also reduce the amount of planning objections and speed up the planning process for renewable energy sources identified as major problem by the RDAs. This process could be supported by devolving national targets to local authorities coupled with stronger enforcement of non-compliance and incentives to meet or exceed them. The Draft National Planning Policy Framework (Department for Communities and Local Government 2011) appears to favour renewable energy in the planning process but renewable policy still takes a backseat to regeneration and economic development and it is unclear how the new LEPs will be able to use informal renewable networks and infrastructure as well as information on local businesses compiled by the RDAs to move the transition process forward or whether the abolishment of RDAs and regional spatial strategies may result in a planning and administrative vacuum that is filled by powerful lobbying groups.

Conclusion

Climate change and energy security are the main drivers of the transition process towards a low-carbon socio-technical energy regime. There are a number of possible ways to achieve this transition but in the long run, renewable energy generation is imperative. The UK is characterized by a highly centralized system where efficiency gains (low-cost energy) were the main goal for private producers, grid operators and suppliers. In order to unlock the existing energy system, a number of changes must occur simultaneously. First, the comparative analysis at the national scale together with results from econometric analysis (Johnstone *et al.*, 2010) demonstrate that strong government incentives for demand creation (such as FITs) and technology push (public R&D investment) are necessary to speed up deployment and development of RETs. Manipulation of landscapes in which energy regimes are embedded is essential. Second, the UK has an R&D, innovation and skills gap in most renewable technology areas that needs to be closed rapidly to take advantage of the "green revolution" and thus support niche development. The recent increase in R&D budgets and patenting activity supplemented by support or RETs by DECC, BIS and NPS for Energy indicate steps in the right directions but may be funded insufficiently for the energy sector to meet its targets (it is estimated that £100 billion need to be invested between now and 2020 to meet the targets set out in the roadmap). Third, in order to speed up niche innovations, a multi-scalar approach to energy transitions should be applied with sub-national policies complementing national policies. Regional and local policies can take advantage of locally specific regime configurations, benefit from localized spillovers, help maintain technological diversity and are more likely to enrol a large number of actors in the transition project, triggering the development of common regional visions that will be easier to implement than "distant" national guidelines. The recent change in legislation to allow local authorities to own and benefit economically from renewable energy projects and regional capacity studies for local authorities to identify locally specific renewable energy policies are potentially important steps in that direction. However, radical changes to planning and energy policies could generate uncertainty and further delay the development and deployment of renewable energy. It needs to be seen whether LEPs will be able to work with local authorities on developing sustainable, local growth strategies built on the creation and deployment of renewable energy sources. As the case of Navarra demonstrated, strong regional support for the deployment of RETs can then result in cluster formation that can improve national comparative advantages in the sector. While the sub-national scale is important to speed up RET deployment and niche development and garner local support for RETs, they cannot function independently from strong incentive policies at the national scale. While it is important to consider the sub-national scale in transition research and policy, an exclusive focus on the sub-national scale and neglect of national and supra-scale processes will result in an incomplete understanding of those processes.

Notes

1. http://cordis.europa.eu/funen/spotlight-07_en.html (accessed 15 September 2011).
2. The reports can be found at http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/ored_news/ored_news/method_assess/method_assess.aspx (accessed 15 September 2011).
3. Japan, the USA and Korea are also major players in innovation and production of renewable energy sources, but in order to control for the impact of EU policies, the paper restricts the comparative analysis to EU countries.
4. http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database (accessed 15 August 2011).
5. http://stats.oecd.org/index.aspx (accessed 18 June 2011).
6. TL3 correspond with NUTS-3 regions in most countries (see Maraut et al., 2008 for more details). RETs include wind, solar thermal, solar PV, geothermal, marine and wave/tidal technologies.
7. Although there are other investment subsidies, the figure does not compare favourably with the €136 million invested in Navarra (a region of 500,000 people) between 1995 and 2004 (Fairless, 2007) or the $1.2 billion of subsidies provided by the German government for solar PV firms in East GE until 2008 (GTAI, 2009).
8. http://www.nwda.co.uk/areas-of-work/supporting-business/key-sector-support/energy–environment.aspx (accessed 15 September 2011).
9. http://www.envirolinknorthwest.co.uk/ (accessed 15 September 2011).
10. "Wave hub is a marine testing facility whose first customer is Ocean Power Technologies and is complemented by the Peninsula Research Institute for Marine Renewable Energy, a centre of excellence delivering world-leading research, facilities and technology transfer in marine energy, excellent port infrastructure and an established supply chain in the South West of England" (www.wavehub.co.uk).
11. www.innovateuk.org/deliveringinnovaiton/technology-and-innovation-centres/offshore-renewable-energy.ashx (accessed 15 September 2011).
12. http://www.communities.gov.uk/documents/planningandbuilding/pdf/1631904.pdf

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