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Emerging energy geographies: Scaling and spatial divergence in EUropean electricity generation capacity

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Abstract

This paper presents an evaluation of the impact of the related EU internal energy market and renewable energy policies by exploring the (sustainable) energy transition in the EUropean electricity sector and drawing on the emerging literatures on energy geographies. We use evidence aggregated from plant-level data on installed electricity generation capacity in the EUropean electric utilities sector over the period 1990–2013 to demonstrate how the unintended interaction between EU policies on energy market liberalization and climate change have led to new renewable energy entrants and more widely dispersed ownership of total generation capacity. Our empirical results suggest that six energy geography concepts enable deeper insights into the spatiality of the EUropean energy transition. Specifically, we find that territoriality and scaling are key lenses for interpreting the differentiated change processes occurring at EUropean, subregional and national levels. The EUropean energy transition is unlikely to converge onto a single trajectory any time soon, but particularly subregional approaches are argued to offer policy-makers with more spatially cognizant and effective levers.

Keywords

Energy geographies, energy transition, European Union, generation capacity, internal energy market, renewable, spatiality, subregional patterns

Introduction

The European electricity generation sector has been subject to several high-profile European Union (EU) policy interventions over the last two decades,

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aiming to facilitate a transition to an integrated and liberalized internal energy market characterized by significant renewable electricity generating capacity. These EU policies have sought to create an (albeit contested) pan-European geo-energy space (Bridge et al., 2013; Mane-Estrada, 2006), which more recently has been reinvented under the auspices of the EU Energy Union (Bouzarovski et al., 2015). Through this Energy Union the European Commission (2015) remains committed to ensuring cost-effective achievement of its 2030 target for the integration of renewables (RES) and achieving a seamless internal energy market (IEM), to benefit citizens and enhance security of supply.

In this paper we seek to contribute to the growing literature on the spatial dimension(s) of sustainability transitions (Coenen et al., 2012), particularly with respect to (renewable) energy development (Bridge et al., 2013; Haas et al., 2008; Verbong and Geels, 2007). This 'energy geographies' focus (Calvert, 2016) on the EUropean energy transition in our case specifically emphasises the multiply embedded nature of EUropean electricity generation, e.g., spatially, temporally, physically, institutionally, etc. (Goldthau, 2014; Hess, 2004). Using this economic geography (Coenen et al., 2012) approach our paper responds to calls for research on energy transitions as spatially-constituted phenomena and the need to assess 'which geographical futures are being created by the low carbon transition' (Bridge et al., 2013: 332).

Drawing on a database of European power generation assets, we present a longitudinal assessment of the energy transition occurring in the EUropean electricity sector and, in light of the EU policies on the IEM for electricity and the contribution of renewable (RES) technologies, contribute to previous assessments of EU energy policy (e.g., Green, 2006; Held et al., 2006; Jacobsson et al., 2009; Jamasb and Pollitt, 2005; Joskow, 2008; Newbury, 2005; Percebois, 2008; Verbruggen et al., 2015). Our approach provides an illustration of the emerging energy geographies that result from the interaction between the EU IEM and RES policy initiatives, by tracking the changing ownership structures and investment choices of European electricity utilities and other investors at different scales (Bouzarovski, 2010; Bouzarovski and Herrero, 2017). Specifically, we offer new evidence of changes in the asset (ownership) concentration of power generation and the dominance of national champions (Domanico, 2007), by exploring the longitudinal trends in capacity ownership in the electricity sector over the period of successive EU energy policy initiatives (Eikeland, 2011; Padgett, 1992; Torriti, 2010). Aggregating data at national, subregional and EU scales allows us to provide a multi-level assessment of the extent to which emerging concepts associated with the geographies of energy transition (Bridge et al., 2013; Calvert, 2016; Coenen et al., 2012) provide for new insights into the spatial constitution of the changing EUropean electricity sector.

To achieve this spatial sensitivity we draw on six concepts that Bridge et al. (2013: 339) have suggested as a 'basic conceptual tool kit with which to develop richer understandings of space and spatial change than are characteristic of current policy approaches to energy transitions: these are discussed in the next section and presented in Table 1. This energy geographies perspective foregrounds spatial difference, relations of position and connection, spatial configuration and scale of organization, and asks what has and has not changed (Bridge et al., 2013).

The resulting exploration of the EUropean energy transition as a multi-scalar, spatially differentiated (Bridge et al., 2013; Charron, 2016) process provides a contribution to 'capturing' the (changing) geographies of the ownership of EUropean power plant assets over a period of almost two and a half decades (1990–2013) that coincides with the major phases in the EUropean energy transition policy process. The following two sections provide further details of our conceptual approach, including Bridge et al.'s (2013) six concepts, before we describe our methodology. We then discuss our findings before concluding with comments on policy implications and future research.

Geographical components of sustainability (energy) transitions

The increasing interest in geographical perspectives on socio-technical (energy) transitions reflects the '(re)surge(nce)' of energy at the heart of geographic research (see Calvert (2016) for an account of the historic role of energy in geography scholarship).

Table 1. Overview of key energy geography concepts and indicative findings.

Energy geographies	Definition	Indicative findings
Scaling	• 'Scale' refers here to the material size and areal extent of phenomena. It describes the different geographical forms in which different energy technologies can be deployed—[…]. It can also describe the varying geographical reach of different political structures – such as local, regional and national government; and forms of economic organisation – differentiating, for example, a businesses operating in only one locality from a transnational corporation' (Bridge et al., 2013: 337).	• Growth in total installed generation capacity • Increasing number of (new) owner-operators • Changing fuel sources/mixes • Growth in renewable capacity • Trends and variation across EU, subregions and member states
Location	• 'Location' here is both an absolute characteristic (latitude and longitude) and a relative one, describing the 'relational proximity' of one element in the system to another. While absolute location is fixed and unchanging, relative location can be highly dynamic.' (Bridge et al., 2013: 334)	• Role of natural resource endowments • Continuation and disappearance of 'energy islands' (Iberia vs. Baltics)
Territoriality	• Territoriality refers to the relationship between social and political power structures and their imposition, organisation and execution over distinct geographical spaces (Brenner et al., 2003). As such territoriality reflects the role, authority and/or commercial power of utilities, municipalities and states in driving the processes behind energy transitions that lead towards greater levels of either centralisation or decentralisation within defined regional spaces (Bridge et al., 2013). • Assessing the territoriality of energy infrastructure in terms of contiguity (dispersion/density); connectivity (Hess, 2004); and centralisation (Bridge et al., 2013).	• Falling generation capacity ownership concentration rates (greater dispersion) • Relative decline of Top 10 largest gencap owners • Some MS still dominated by one large gencap owner • Continued dominance of 7 Brothers • No new pan-European utilities • Strong emergence of two new, highly dispersed groups of asset owners • Trends and variation across EU, subregions and member states • Role of subregional regulatory collaboration (ERIs) in shaping trends • Interaction effects between IEM and RES

(Continued)

Table 1. (Continued)

Energy geographies	Definition	Indicative findings
Spatial differentiation (convergence vs. divergence)	• Spatial differentiation reflects the realisation that, despite strong forces of convergence, energy transitions are likely to proceed at varying paces in different spaces. This will inevitably lead to uneven development across continents, countries, regions and urban areas. Understanding such differences will be important for assessing progress overall and developing policy-advice better suited to different localities (Bridge et al., 2013). • '[…] a process of simultaneous equalisation and differentiation' (Bridge et al., 2013: 337). • Emerges from the locations, landscapes and territorialisation that constitute the sustainability (energy) transition (Bridge et al., 2013).	• 'Walls' in renewables ratios • 'Floors' in asset ownership concentration rates • Emergence of 2 new, highly dispersed groups of asset owners • Some countries still dominated by one large gencap owner • German 'Energiewende'
Spatial embeddedness (path dependence)	• Spatial embeddedness extends the insights of spatial differentiation by recognising the significant path dependency created by geographical niches and incumbents. Spatial embeddedness relates to the influence of 'economic, material and cultural aspects of energy systems' (Bridge et al., 2013: 338) and which significantly shape its location-bound evolution. • It also 'refers to both the sunk costs of capital investment and the place-based cultures (of consumption and production) that surround certain energy technologies' (Bridge et al., 2013: 338).	• Relative decline of Top 10 largest gencap owners • No new pan-European utilities • Role of natural resource endowments • Continuation and disappearance of 'energy islands' (Iberia vs. Baltics) • German 'Energiewende'
Landscape	• Landscape 'describes the assemblage of natural and cultural features across a broad space and the history of their production and interaction', as well as the 'constellation of activities and socio-technical linkages associated with energy capture, conversion, distribution and consumption' (Bridge et al., 2013: 335).	• Continuation and disappearance of 'energy islands' (Iberia vs. Baltics) • German 'Energiewende'

EU: European Union.

However, while the literature on geographies of sustainability (energy) transitions is clear in its aim to add a spatial sensitivity to the broader transitions literature (Hansen and Coenen, 2015; Truffer et al., 2015), developing a shared conceptual foundation for studying the (possible future) geographies of sustainability (energy) transitions is ongoing (Bridge et al., 2013; Coenen et al., 2012; Hansen and Coenen, 2015; Truffer and Coenen, 2012). Bridge et al. (2013) is referenced as a central contribution in this conceptual agenda (Calvert, 2016; Hansen and Coenen, 2015) that has been welcomed for contributing to establishing such a (shared) vocabulary or conceptual roadmap for clarifying the specificities of a geographical perspective on sustainability (energy) transitions (Calvert, 2016). In detail, Bridge et al. (2013) suggest six basic concepts that can be used for mapping continuity and change associated with geographies of sustainability (energy) transition(s), and which thus inform choices in the realisation of potential energy futures. They include location; landscape; territoriality; spatial differentiation; scaling; and spatial embeddedness. We define and explore these six concepts in more detail below (and summarize them and our findings in Table 1). This approach was adopted in order to provide an interpretive lens for our data analyses, because the concepts are best understood in relation to our emergent findings. Each one of these concepts reflects the acknowledgement that spatiality shapes energy systems and influences their capacity for transformation. In doing so, they provide a valuable conceptual lexicon for exploring the geographical implications and emerging futures of the EU's and member states' energy policies and investment choices.

European Union energy policy-making

The importance and salience of the energy sector within the EUropean project is most directly demonstrated by the fact that two of the three founding treaties focused on the sector (McGowan, 1989). Early initiatives emphasized both security of supply and the establishment of a single market for energy, but until the early 1980s the emphasis was on the former rather than the latter, at which time the agenda began to change towards a focus on the nascent IEM (McGowan, 1989). Over time EU energy policy has broadly followed changing political paradigms from statism via liberalism towards increased interventionism/dirigisme (Goldthau and Sitter, 2014), by developing a series of related policies for liberalization and integration of the IEM and the promotion of RES generation capacity for electricity. IEM and RES policies for electricity have particularly gathered pace and depth since 2000, with directives seeking to establish a single competitive EU electricity market (European Parliament and the Council, 1996, 2003, 2009b: EU Directives 1996/92/EC; 2003/54/EC; 2009/72/EC respectively) and the 'greening' of the EU energy sector through the promotion of RES as part of a broader response to climate change (European Parliament and the Council, 2001, 2009a: EU Directives 2001/77/EC; 2009/28/EC respectively; European Commission, 2014). In contrast to the IEA's proposal (OECD/IEA, 2013) for significantly more investment, however, the EU's promotion of IEM and RES was pursued without large flows of additional resources, although the latest draft policies (European Commission, 2015) now note the need for access to finance, with the private sector being expected to bear most of the costs of these additional investments. The EUropean electricity sector has therefore been and remains subject to the IEM and the promotion of RES as two policy domains that are fundamentally changing its nature. In particular, there is a question over *where* that investment will materialize (Bridge et al., 2013). To understand the low-carbon or sustainability energy transition, we examine the choices of key industry actors, such as asset investors and owners, and spatiality in shaping the emerging socio-economic, technological and political landscapes.

Early assessments of the EU's energy policies suggested that progress with regard to liberalization was based on a stepwise approach and minimum compliance among the core EU15 countries; moreover, it has been argued elsewhere that mergers and acquisitions have led to increasingly high market concentration in the EUropean electricity sector, with a handful of national champions expanding their ownership interests in neighbouring countries (Green, 2006; Jamasb and Pollitt, 2005). Over time, significant progress has also been made with the promotion of RES electricity generation capacity, largely through the public provision of financial incentives for supply (e.g., renewable energy certificates, feed-in tariffs, etc.), with the result that currently these technologies are increasingly recognized as viable alternatives for investment, explicitly promoted through the EU's climate change commitments within the extended 2030 targets (European Commission, 2014) and lately through the pursuit of an EU 'Energy Union' (European Commission, 2015). However, the historically parallel but separate development of the IEM and RES directives has raised questions over the mutual impacts of renewables promotion and efforts to increase competition among electric utilities (Szabó and Jäger-Waldau, 2008).

Furthermore, the institutionally and geographically nested nature of energy policy has created gaps between the ideal-type and energy policy as actually applied across the EU and by its member states (Andersen and Sitter, 2009; Pelkmans, 2001; Von Hirschhausen and Waelde, 2001), with the result that national politics and policy-making often continue to override the processes of Europeanization in the energy domain (Goldthau and Sitter, 2014; Lodge, 2002). In recognition of these findings, there are increasingly calls for governance of energy infrastructure to become more polycentric and multilevel (Goldthau, 2014). The main thrust of this argument is based on the belief that while institutions such as those of the EU can steer (but also obstruct) radical innovation processes, they do so in spatially differentiated ways (Coenen et al., 2012). This spatial differentiation in energy policy preferences is partly explained by the comparative institutional advantages of EU member states' 'varieties of capitalism' (Hall and Soskice, 2001; Schmidt, 2003, 2009), which continue to exert their influence at the national level, despite some institutional convergence at EU level (European Commission, 2012). The differing degrees of institutional thickness and capacity of member states contribute further to regional divergence rather than convergence in EU energy policy outcomes, particularly in peripheral regions (Charron, 2016; Coenen et al., 2012).

The effects of diverse energy landscapes and associated territoriality at the scale of member states (Bouzarovski and Herrero, 2017) on the geographies of electricity production have been highlighted (albeit with other theoretical framings) in work on electric utility internationalization (Kolk et al., 2014), studies of EU member states' policy-making in response to climate change, changing acceptance of fossil fuels and divergent perceptions of a need for the promotion of renewables (Verbruggen et al., 2015) and the spatial inequalities associated with energy transition (Bouzarovski and Herrero, 2017). Elsewhere, the legacy of the Soviet Union has created clear path dependence for the Baltics and the 'eastern' regions of the EU in terms of shaping their respective energy transition (Bouzarovski et al., 2015; Ürge-Vorsatz et al., 2006; Von Hirschhausen and Waelde, 2001).

For the purposes of our study it is deemed neither appropriate nor necessary to repeat a detailed account of the differing approaches and degrees to which each EU member state has approached the liberalization of the electricity sector (see: Domanico, 2007; Jamasb and Pollitt, 2005; Padgett, 1992) and promotion of renewables (see: Kitzing et al., 2012; Klessmann et al., 2011; Lipp, 2007; Meyer, 2003; Reiche and Bechberger, 2004). Equally, despite the clear relevance to the electricity sector of EU rules concerning state aid (Cansino, et al., 2010), we do not address directly the new 2014 state aid guidelines because they emerged after the conclusion of our period of study. We argue that the sensitivity for the specifics of the diverse approaches at the scale of the member states is revealed in the (re)scaling at EU, subregional and national levels in terms of electricity generation asset ownership and technologies and in the resulting geographies of the EUropean power sector. For the purposes of this paper we focus on the emerging geographies of ownership concentration in electricity generation capacity, to reflect EUrope's 'diverse economic and social geography, as well as its leadership role and declarative commitment towards climate change mitigation targets' (Bouzarovski and Herrero, 2017), its varied natural resource endowments and resulting potentials for renewable energy capacity (Boeters and Koornneef, 2011; Šúri et al., 2007).

We argue that despite the EU's efforts to drive energy policy harmonization and integration, supported by observed convergence in policy instruments

Table 2. EU24 subregions and member countries.

EU subregion	EU24 member countries
Baltic	Estonia, Latvia, Lithuania
Central East	Austria, Czech Republic, Germany, Hungary, Poland, Slovakia, Slovenia
Central South	Austria, France, Germany, Greece, Italy, Slovenia
Central West	Belgium, France, Germany, Luxembourg, Netherlands
Northern	Denmark, Finland, Germany, Norway, Poland, Sweden
South West	France, Portugal, Spain
FUI	France, UK, Ireland

Source: Council of European Energy Regulators (CEER).

for promoting renewables (Kitzing et al., 2012), the underlying nature of energy flows and assets combined with varying resource endowments and institutional diversity among member states is likely to result in diverging patterns of fuel mixes and capacity ownership across member states and subregions. Identifying and understanding the dynamics leading to such differentiation is vital for informing policy development and decision making among industry stakeholders.

Methods

We draw upon a unique dataset derived from the Platts 'PowerVision' database[1] which provides specific data on power plant and information on installed and planned generation capacity in the European power sector. The PowerVision database has been developed using detailed granular information collected continuously over ten years by a dedicated product team. This team reviews company reports and releases, official government gazettes and filings, tender postings and local press, as well as addressing direct enquiries to utilities and developers. These data are cross-referenced to publicly available inventories and benchmarked to aggregate statistics.

To study trends in investment and ownership of EUropean power generation assets, we used data for installed and operating plants measured in megawatt (MW) capacity between 1990 and 2013 for our analyses. Geographically, for our sample we drew on data available for 23 European Union (EU) member states plus Norway. This sample is defined by the seven subregions included in the EU Electricity Regional Initiatives (ERI), launched by the European Regulators' Group for Electricity and Gas (ERGEG) in 2006, and which for the purposes of simplicity we refer to as the 'EU24'. By drawing on this particular sample we are able to provide insights into three scales of energy governance because, in addition to the data for the combined EU24 region and individual EUropean countries, we also explore developments at the 'subregional' level (see Table 2).

In fact, the ERGEG ERI subregions introduced a new scale of EU energy territorialisation for electricity, by bringing together national regulatory authorities, transmission system operators and other stakeholders in a voluntary process for testing cross-border approaches and advancing integration at the subregional level, as a step towards the creation of a well-functioning IEM.[2] This approach allows us to investigate the potential for and effects of polycentric governance of the type that Goldthau (2014) identified with the EU IEM to shape future geographies of electricity asset ownership.

Given the strongly spatially embedded nature of energy infrastructure systems, ERIs generally incorporate neighbouring countries, with some countries simultaneously being members of multiple subregions. France and Germany – through their absolute locations – emerge as important for increasing the relative proximity of the ERIs in which they are included; while in contrast the UK, for example, is only part of the most 'dispersed' and somewhat peculiar grouping of the FUI ERI (France–UK–Ireland). Similarly, Norway is included as an integral member of the highly integrated Nordic regional energy market. We retain consistently the ERI grouping for the entire period under review to offer a new scaling of the energy territoriality of EUropean countries, reflecting their locations, historic relationships and current cooperation. Thus including the pre-2006 data allows changing historic concentration of ownership to be placed in context for contemporary subregional scaling of integration processes. The resulting seven subregions and their member countries included in the ERIs are shown in Table 2.

Table 3. Fuel classification for generation capacity.

Fuel categories	Generating technology/fuel type
Non-renewable	Nuclear, other, coal/cogen, coal, boiler/cogen, steam boiler, combustion turbine/cogen, combined cycle/cogen, combined cycle, duct firing, combustion turbine, reciprocating engine
Renewable	Geothermal, hydro, solar, wind, offshore wind, waste (includes biomass), pumped storage hydro

Source: Platts PowerVision data and authors.

Our analyses are based on aggregate data for 'Operator Main Holding Companies' in the countries covered. These are the firms that own a diverse portfolio of often limited liability, plant-specific operating units, many of which are known as the widely familiar utilities. Our analyses of these data are operationalized through the calculation of generation capacity ownership concentration rates, aggregation of plant level data by 'fuel' type and the alignment of cross-sectional data in correspondence to years of significant EU directives. Because our research is based on installed generation capacity data we did not evaluate industry changes in terms of the levels of actual electricity supplied. Such more complex analyses require the inclusion of electricity production data, which depend on plant-specific capacity factors and a range of other variables that were not considered in this study, but would offer potentially insightful, alternative insights into the EUropean energy transition. Particularly for renewable technologies, the intermittent nature of, for example, photovoltaic and wind electricity generation, as well as ceilings on the load factors of specific renewables installations, result in significantly lower annual production figures than their reported specified capacities (e.g., Pepermans et al., 2005). For non-renewable energies, the merit-order ranking of technologies and added carbon prices, conversion losses and maintenance among others determine effective levels of electricity supplied.

Rates of concentration of generation capacity ownership are calculated according to the Herfindahl–Hirschman Index (HHI), a widely used measure of firms' sizes in relation to their industry, used here as an indicator of the amount of control exercised by individual firms over the total stock of generation capacity operating in a pre-defined geographical area. The HHI is calculated by summing the squares of generation capacity shares of the 50 largest Operator Main Holding Companies. Generation capacity shares are expressed as percentages of total installed capacity in a particular country or subregion in a given year. Theoretically, the most dispersed distribution of ownership for the HHI50 would be an ownership share of 2% for each firm, represented by a HHI50 score of 200. The higher the HHI50 score the more concentrated the ownership of generation capacity (to a maximum of 10,000). Importantly, this method of calculation means that multiple ownership structures representing different degrees of ownership concentration can result in a higher HHI50 score. For comparison we also provide HHI10 figures based on the largest 10 generators; the results were largely identical.

Because installed capacities are differentiated in the Platts database according to fuel sources, we aggregated plant level data, as shown in Table 3, and calculate non-renewable and renewable shares of total installed generation capacity for particular years, countries and subregions. Furthermore, we present cross-sectional data corresponding to years of significant EU directives (1996, 2003, 2009, 2013) for trends in ownership concentration, changing fuel mixes and the dominance of the largest capacity owners in each country and subregion (see Table 4). We assessed the changing industry structures for the 10 largest firms in each country and subregion at the start and end of the period studied (1996, 2013), see Table 5. This approach was adopted in order to provide indicative insights into policy effects, although it was not possible to produce generalizable results. This overall time period includes the year in which the EU internal electricity market directive was adopted (1996) and ends with 2013, the last full year for which data were available to us. We used all years of data at the firm level to evaluate the changing ownership concentration rates among the largest electric utilities relative to aggregate renewables operators (see Figure 1) and to study subregional trends (see Figure 2).

Table 4. EU subregional and country electricity generation capacity fuel mixes, major capacity owners' contributions and HHI[e] 50.

EU region/ member country[a]	Total installed capacity (MW)				Ratio of Installed non-renewable[b] capacity (% of total) to installed renewable[c] capacity (% of total)				Contribution to total generation capacity by the largest capacity owner per region/country (% of total)				HHI 50			
	1996	2003	2009	2013	1996	2003	2009	2013	1996	2003	2009	2013	1996	2003	2009	2013
European Union[d]	628,569	698,615	870,838	1,008,078	75:25	72:28	70:30	64:36	19.2	17.6	15.2	13.5	683	588	483	436
Baltic	11,708	11,800	9,044	9,738	80:20	78:22	69:31	66:34	47.6	49.2	31.0	30.2	3,342	3,389	2,548	2,154
Lithuania	6,340	6,587	3,688	4,580	88:12	85:15	71:29	71:29	87.9	88.1	75.9	64.3	7,790	7,807	5,931	4,352
Latvia	2,063	2,106	2,422	2,638	26:74	26:74	36:64	39:61	99.4	98.0	96.2	95.4	9,884	9,608	9,262	9,097
Estonia	3,305	3,107	2,934	2,422	100:0	100:0	94:6	86:14	97.1	96.8	92.3	87.9	9,427	9,380	8,524	7,747
Central East	185,004	205,535	236,513	293,949	85:15	78:22	70:30	63:37	14.3	12.9	11.3	11.9	626	559	535	534
Austria	16,705	17,144	18393	21,457	33:67	31:69	29:71	29:71	45.7	43.5	37.2	38.9	2,453	2,243	1,773	1,861
Czech Republic	14,405	16,668	17233	19,951	86:14	88:12	85:15	77:23	74.2	71.2	67.3	62.9	5,583	5,140	4,611	4,091
Germany	106,601	120,024	147,819	192,212	90:10	79:21	68:32	57:43	24.8	21.3	17.5	16.5	1,470	1,249	1,094	983
Hungary	7225	8596	9032	8366	99:1	99:1	93:7	87:13	30.3	29.7	34.0	40.1	2,089	1,864	1,846	1,869
Poland	31,051	32,320	34,578	38,593	94:6	94:6	92:8	84:16	33.7	36.1	35.4	33.1	1,776	1,874	1,788	1,548
Slovakia	6375	7823	6219	7052	63:17	68:32	60:40	55:45	76.0	76.3	82.8	73.6	5,988	5,973	6,896	5,513
Slovenia	2642	2960	3239	3487	69:31	70:30	66:34	60:40	70.2	72.4	74.7	70.9	5,578	5,758	6,022	5,430
Central South	301,586	329,062	408,965	510,677	77:23	73:27	70:30	64:36	34.0	31.5	27.4	22.6	1,549	1,347	1,062	853
Austria	16,705	17,144	18,393	21,457	33:67	31:69	29:71	29:71	45.7	43.5	37.2	38.9	2,453	2,243	1,773	1,861
France	105,875	107,933	116,515	124,069	75:25	76:24	73:27	70:30	93.7	91.6	85.9	81.1	8,788	8,409	7,410	6,624
Germany	106,601	120,024	147,819	192,212	90:10	79:21	68:32	57:43	24.8	21.3	17.5	16.5	1,470	1,249	1,094	983
Greece	9026	11,920	14,274	17,074	72:28	71:29	71:29	69:31	99.7	96.9	85.2	70.1	9,938	9,396	7,335	5,196
Italy	60,737	69,081	108,725	144,783	71:29	71:29	76:24	69:31	58.2	53.1	34.7	27.3	3,746	3,107	1,520	1,083
Slovenia	2642	2960	3239	3487	69:31	70:30	66:34	60:40	70.2	72.4	74.7	70.9	5,578	5,758	6,022	5,430
Central West	244,467	263,326	307,406	367,268	84:16	79:21	72:28	66:34	41.0	38.1	33.0	28.1	2,125	1,859	1,506	1,223
Belgium	13,383	15,515	19,211	20,690	89:11	90:10	84:16	70:30	86.5	82.2	74.7	61.4	7,554	6,880	5,688	3,957
France	105,875	107,933	116,515	124,069	75:25	76:24	73:27	70:30	93.7	91.6	85.9	81.1	8,788	8,409	7,410	6,624
Germany	106,601	120,024	147,819	192,212	90:10	79:21	68:32	57:43	24.8	21.3	17.5	16.5	1,470	1,249	1,094	983
Luxembourg	1181	1600	1608	1623	3:97	27:73	27:73	27:73	96.4	71.1	70.8	73.4	9,284	5,548	5,494	5,754
Netherlands	17,427	18,254	22,253	24,210	97:3	93:7	88:12	88:12	26.6	22.6	18.5	21.2	1,863	1,601	1,182	1,228

(Continued)

Table 4. (Continued)

EU region/ member country[a]	Total installed capacity (MW)				Ratio of Installed non-renewable[b] capacity (% of total) to installed renewable[c] capacity (% of total)				Contribution to total generation capacity by the largest capacity owner per region/country (% of total)				HHI 50			
FUI	185,492	198,682	236,427	257,146	83:17	84:16	82:18	77:23	61.2	57.4	49.1	46.3	3,910	3,438	2,559	2,275
France	105,875	107,933	116,515	124,069	75:25	76:24	73:27	70:30	93.7	91.6	85.9	81.1	8,788	8,409	7,410	6,624
UK	75,103	85,045	110,955	119,390	94:6	94:6	91:9	83:17	19.0	17.8	14.4	14.6	1,191	928	710	618
Ireland	4514	5704	8957	10,839	89:11	87:13	77:23	70:30	78.8	71.6	44.2	39.7	6,649	5,459	2,506	2,081
Northern	223,943	243,515	279,182	338,609	71:29	65:35	60:40	54:46	15.5	14.5	12.7	10.7	699	625	578	526
Norway[e]	28,044	28,587	31,359	36,394	0:100	0:100	5:95	8:92	36.3	36.2	33.6	30.1	1,586	1,568	1,372	1,125
Sweden	34,121	34,029	35,574	37,854	45:55	43:57	42:58	40:60	53.4	51.4	48.3	45.4	3,352	3,151	2,863	2,602
Finland	14,574	16,251	17,167	19,116	69:31	68:32	66:34	60:40	29.4	26.3	26.7	30.6	1,538	1,344	1,390	1,569
Denmark	9552	12,304	12,685	12,074	90:10	69:31	67:33	53:47	63.0	48.0	48.4	39.9	4,156	2,876	2,909	2,381
Germany	106,601	120,024	147,819	192,212	90:10	79:21	68:32	57:43	24.8	21.3	17.5	16.5	1,470	1,249	1,094	983
Poland	31,051	32,320	34,578	38,593	94:6	94:6	92:8	84:16	33.7	36.1	35.4	33.1	1,776	1,874	1,788	1,548
South West	164,195	182,990	242,513	264,604	70:30	70:30	67:33	66:34	60.4	54.0	41.3	38.3	3,943	3,217	2,054	1,826
France	105,875	107,933	116,515	124,069	75:25	76:24	73:27	70:30	93.7	91.6	85.9	81.1	8,788	8,409	7,410	6,624
Portugal	8729	10,903	16,122	16,747	51:49	58:42	53:47	50:50	87.4	70.5	65.1	56.7	7,692	5,214	4,493	3,403
Spain	49,591	64,154	109,876	122,831	63:37	61:39	62:38	61:39	37.3	31.7	21.5	20.3	2,747	2,069	1,322	1,246

Source: Platts PowerVision and authors' calculations.

Notes:

a. The ERGEG ERI subregions used in this study are not mutually exclusive and some EU24 member countries are members of more than one subregion.

b. Non-renewable fuels include nuclear, other, coal/cogen, coal, boiler/cogen, steam boiler, combustion turbine/cogen, combined cycle/cogen, combined cycle, duct firing, combustion turbine, reciprocating engine.

c. Renewable fuels include geothermal, hydro, solar, wind, offshore wind, waste (includes biomass), pumped storage hydro.

d. This covers the 24 countries that are included in the regional sub-groups: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

e. Norway is included as an integral member of the highly integrated Nordic regional energy market, despite not being an EU member.

f. HHI: Herfindahl–Hirschman Index.

Table 5. Shares of European[a] generation capacity: ownership for the ten largest capacity owners.

EU region/ member country[b]	Total number of firms				HHI[d] 10 subregional/ national		Concentration of generation capacity ownership (%) in rank order, largest to smallest Concentration by firm for a given year[e]																			
							Electric Utility 1		Electric Utility 2		Electric Utility 3		Electric Utility 4		Electric Utility 5		Electric Utility 6		Electric Utility 7		Electric Utility 8		Electric Utility 9		Electric Utility 10	
	1996	2003	2009	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013
European Union[c]	1,033	1,511	1,893	2,084	683[d]	415[d]	20	13	10	8~	9	7	7	6*	6	5	4	4	4	4	2	4	2	3	2	2
Baltic	10	14	22	33	3,342	2,153	48	30	27	26	18	23	3	5	2	4	1	2	1	2	0	2	0	1	0	1
Lithuania	4	5	8	15	7,790	4,351	88	64	6	10	3	8	3	5	–	4	–	3	–	2	–	1	–	1	–	1
Latvia	2	4	5	7	9,884	9,097	99	95	1	2	–	1	–	1	–	0	—	0	–	0	–	–	–	–	–	–
Estonia	4	5	9	14	9,427	7,746	97	88	2	3	0	2	0	2	–	1	–	1	–	1	–	1	–	1	–	0
Central East	218	239	349	403	626	504	14	12*	13	11~	8	9	6	7	6	6	5	5	4	4	4	4	3	3	3	3
Austria	24	27	42	45	2,448	1,821	46	39	10	9	9	8	9	8	7	7	4	7~	3	3	3	3	3	3	2	3
Czech Republic	36	45	73	80	5,583	4,088	74	63	6	9*	4	4	3	4	2	3	2	3	1	2	1	1	1	1	1	1
Germany	88	119	161	184	1,461	973	25	16*	22	16~	14	14	9	10	7	9	2	5	2	5	1	2	1	1	1	1
Hungary	15	19	31	40	2,051	1,853	30	40	26	7	18	7	12	6	4	5	4	5	3	5	1	5	1	3	1	2
Poland	24	27	43	62	1,772	1,535	33	35	18	15	9	8	9	8	8	7	6	5	3	2	2	2	2	2	2	2
Slovakia	13	14	14	18	5,988	5,511	76	74	14	7*	3	4	2	3	2	2	1	2	1	1	0	1	0	1	0	1
Slovenia	4	4	4	5	5,455	5,430	69	71	25	19	5	6*	1	4	–	1	–	–	–	–	–	–	–	–	–	–
Central South	240	440	595	657	1,549	835	34	23	12	10*	11	8	8	8	5	6	3	5	3	3	3	3	3	2	2	2
Austria	24	27	42	45	2,448	1,821	46	39	10	9	9	8	9	8	7	7	4	7~	3	3	3	3	3	3	2	3
France	21	71	123	138	8,788	6,624	94	81	3	5~	2	3	1	3	0	2	0	2*	0	1	0	1	0	0	0	0
Germany	88	119	161	184	1,461	973	25	16*	22	16~	14	14	9	10	7	9	2	5	2	5	1	2	1	1	1	1
Greece	2	2	6	7	9,938	4,953	100	71	0	9	–	7	–	4	–	4	–	3	–	2	–	–	–	–	–	–
Italy	111	230	280	304	3,745	1,062	58	27	17	10*	7	9	5	8	5	5	1	4	1	3	1	3	0	2	0	2
Slovenia	4	4	4	5	5,455	5,430	69	71	25	19	5	6*	1	4	–	1	–	–	–	–	–	–	–	–	–	–
Central West	183	318	421	459	2,125	1,218	41	28	13	11~	11	10*	8	8	7	7	4	6	3	6	1	3	1	3	1	1
Belgium	28	42	55	62	7,554	3,949	86	61	8	9	4	6*	1	5	0	4	0	2	0	2	0	2	0	1	0	1
France	21	71	123	138	8,788	6,624	94	81	3	5~	2	3	1	3	0	2	0	2*	0	1	0	1	0	0	0	0
Germany	88	119	161	184	1,461	973	25	16*	22	16~	14	14	9	10	7	9	2	5	2	5	1	2	1	1	1	1
Luxembourg	22	67	68	68	9,284	5,754	96	73	1	19	1	2	1	1	1	1	0	1	0	1	0	0	0	0	0	0
Netherlands	39	47	51	53	1,861	1,221	27	21	21	20	19	14	18	8~	5	7	2	7	1	5	1	3	1	3	1	2

(Continued)

Table 5. (Continued)

EU region/ member country[b]	Total number of firms				HHI[d] 10 subregional/ national		Concentration of generation capacity ownership (%) in rank order, largest to smallest Concentration by firm for a given year[e]																			
							Electric Utility 1		Electric Utility 2		Electric Utility 3		Electric Utility 4		Electric Utility 5		Electric Utility 6		Electric Utility 7		Electric Utility 8		Electric Utility 9		Electric Utility 10	
FUI	88	205	338	401	3,910	2,261	61	46	8	5	7	5	5	5	3	3	2	3	2	3~	2	2	2	2	1	2
France	21	71	123	138	8,788	6,624	94	81	3	5~	2	3	1	3	0	2	0	2*	0	1	0	1	0	0	0	0
United Kingdom	68	122	179	227	1,171	590	19	15	17	10	16	10	12	8	7	6	5	4	5	4	3	4	3	3	3	3
Ireland	3	23	52	53	6,649	2,080	79	40	21	16	0	9	–	8~	–	7	–	5	–	4	–	4	–	2	–	1
Northern	568	653	760	835	699	503	15	11	15	11~	11	10*	6	8	5	8	4	4	4	4	3	3	3	3	3	3
Norway[a]	128	139	160	195	1,568	1,098	36	30	9	7	6	5	6	5	6	5	5	4	4	4	2	4	2	3	2	2
Sweden	54	62	74	76	3,346	2,599	53	45	19	19	11	11	4	4~	2	3	1	3	1	2	1	2	1	1	1	1
Finland	83	91	98	100	1,525	1,554	29	31	23	22	7	6	6	6	4	4	3	4	3	3	3	3	2	2	2	2
Denmark	210	235	246	247	4,155	2,380	63	40	11	25~	5	12	5	4	1	2	1	1	1	1	1	1	1	1	1	0
Germany	88	119	161	184	1,461	973	25	16*	22	16~	14	14	9	10	7	9	2	5	2	5	1	2	1	1	1	1
Poland	24	27	43	62	1,772	1,535	33	35	18	15	9	8	9	8	8	7	6	5	3	2	2	2	2	2	2	2
South West	150	391	383	407	3,943	1,821	60	38	11	10~	11	9	6	9	3	6	3	5	2	4	0	3	0	2*	0	1
France	21	71	123	138	8,788	6,624	94	81	3	5~	2	3	1	3	0	2	0	2*	0	1	0	1	0	0	0	0
Portugal	26	41	54	55	7,692	3,399	87	57	7	7	1	7	1	5	1	5	1	3	0	2	0	2	0	1	0	1
Spain	107	189	222	229	2,747	1,239	37	20	35	18	9	17~	6	12	4	4	1	4	1	3	1	3*	1	3	0	3

Source: Platts PowerVision and authors' calculations.

Notes:

a. Norway is included as an integral member of the highly integrated Nordic regional energy market, despite not being an EU member.

b. The ERGEG ERI subregions used in this study are not mutually exclusive and some EU24 member countries are members of more than one subregion.

c. Covers the 24 countries that are included in the regional sub-groups: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

d. HHI 50: Herfindahl–Hirschman Index.

* denotes aggregated solar photovoltaic power developers; ~ denotes aggregated wind-power developers.

e. Note in particular that the data do not refer to specific firms, but rather, for either year, the share of capacity owned by the firm with a given rank in that year. The data do not seek to identify the relative ranking of specific European utilities over time, but rather represent the changing market structure at different levels of analysis over time, with an account of the role of aggregated renewable capacity in this process.

Emerging European geographies of electricity generation capacity

The EUropean energy transition

We begin our analyses by highlighting focused observations on the changes in fuel sources and ownership patterns across EUropean energy assets. We match these observations with key concepts identified by Bridge et al. (2013) in an attempt to demonstrate their relevance for illustrating and interpreting the significance of geographical lenses in understanding sustainability energy transitions (see Table 1). To do so we provide definitions of the six concepts and summarize our main indicative findings for each concept in Table 1. We then assess their relevance to understanding sustainability energy transitions in greater detail through the analysis in this section and the following discussion. This approach adopts an integrative reading of Table 1, in light of the density of the analytical section and our intention to emphasize the exploration of the applicability of these concepts.

Despite the financial crisis and the continuing recession in many European countries (and taking into account nuclear shutdowns and retirement of fossil-fuelled plants due to age, economics and environmental legislation), we find strong growth in total installed generation capacity (see Table 4). In fact, between 1996 and 2013 and across our set of EU24 countries, the total installed capacity increased by 380 GW or 60% to a total of 1008 GW. The biggest absolute increase of installed capacity occurred in the Central South region, with the biggest percentage increases occurring in spatially peripheral Italy, Ireland and Spain. Meanwhile, the isolated Baltic region was the only region to register a decline in installed capacity, most of which was in Lithuania and Estonia, reflecting significant economic restructuring following the end of communism (Ürge-Vorsatz et al., 2006).

Across our sample of EUropean countries and regions, we also witness increasing rates of renewable energy assets being installed, changing the capacity fuel mix in their respective geographies. The EU24 share of non-renewable (fossil and nuclear) to renewable energy capacities has slowly shifted in favour of renewables, from 75:25 to 64:36 between 1996 and 2013. The Central West, Northern and Central South regions witnessed the biggest increases in renewables between 1996 and 2013. Table 4 shows all but the FUI subregion converging to levels of renewables accounting for at least 34% of total installed capacity. There is, however, significant variation at the scale of the member states; for example, in the Northern region, which has made the most progress with its sustainable energy transition. Denmark in particular managed to grow its share of renewable energy capacity from 10% in 1996 to 47% in 2013. In Norway renewables still account for almost 100% of capacity compared with Poland's 16%, reflecting different levels of natural resource endowments and unique domestic energy landscapes and territorialisation of these countries (Von Hirschhausen and Waelde, 2001). Germany, Spain, Italy and the UK are the leading countries in this shift towards renewables.

The rates of change clearly vary between countries and subregions, but this widespread growth in renewables across most European countries is consistent with the EU's Directives on climate change and as such suggests that such high-level goals mandated through EU legislation appear to have had a significant effect on member state policies. The multi-scalar territoriality of EUropean energy policy thus suggests collective progress, featured by spatial differentiation across countries (Table 1). At the same time, however, we acknowledge the importance of national energy policies in translating these directives and driving such progress, and which has led to this spatial differentiation of non-renewable and renewable capacities, reflecting the geographical embeddedness of energy investments (Table 1).

Our second key finding is that rates of concentration of generation capacity ownership are falling across all European regions and countries. Based on our HHI50 for the largest owners of generation capacity in every country and subregion, our results suggest that these rates are declining, the number of owner–operators is generally increasing and thus asset ownership is increasingly dispersed. Furthermore, we find that the ownership concentration of the ten biggest operators in all countries and subregions is declining over time, suggesting some aggregate spatial convergence (Table 1), again an indication that increasing levels of plant ownership dispersal at the asset level are slowly gaining traction. This is consistent with the EU IEM's stated objective to achieve increasingly dispersed asset ownership, raising the level of competition and providing grid access to new capacities. While rates of concentration of generation capacity ownership are largely falling across all subregions and countries, the aggregate changes in the HHI50 for all 24 European countries combined between 1996 and 2013 (683 to 436) mask big variations at the subregional and national scales (Table 4).

The aggregate ownership concentration figures are complemented by the data on the high contributions to the total capacity made by the largest capacity owner in each of these countries and regions (see Table 4). In 2013 the most dominant national utilities still owned as much as 95% (Latvia) of total installed capacity; Estonia, France, Slovenia, Luxembourg, Slovakia and Greece remain firmly in the hands of a single dominant owner of generation capacity. Our data therefore suggest that, since Domanico's (2007) assessment, not much has changed in the sense that there are still 14 European countries in which the three largest suppliers (not including aggregated renewables) continue to own more than 60% of the installed generation capacity. At the other end of the spectrum, there was also relatively little change in terms of the countries with the least concentrated ownership of generation capacity but, there, rates have nonetheless been falling. This finding of limited (spatial) convergence (Table 1) can be compared with earlier research on resource concentration (also measured in terms of HHI) for the EU15+2[3] in seven power generation fuel categories (coal, oil, gas. nuclear, hydro, wind, and others), which had fallen from 2636 in 1990 to 2253 in 2002 (Jamasb and Pollitt, 2005: 18).

More importantly, we note that the increasing total number of firms owning generating capacity in each country or subregion plays a crucial role in driving down overall concentration rates, even if the actual calculations for the capacity ownership HHI are based on the top 10 or top 50 firms only. For example (see Table 5), by 2013 Italy, Denmark, Spain, the UK and Germany had the most dispersed generation capacity ownership in terms of the total number of asset owners (despite the large numbers of individually-owned solar PV and wind power installations being aggregated into single generators in our source database). Meanwhile, Slovenia, Greece, Latvia, Estonia and Lithuania had notably few different owners of generation assets for their national markets. The generation capacity of installed renewables in a country or subregion and the respective total number of operating firms is highly correlated at 0.939 and is significant at 0.01(**): thus it is our contention that, generally, greater levels of renewable energies are associated with more firms owning generation capacity in the EU. This is crucial for understanding the changing (re)scaling of EU electricity generation capacity territorialities (Table 1).

The speed with which this transition is occurring is debatable; and, based on our observation that many European countries still remain dominated by a few large established generators, suggesting spatial embeddedness effects (Table 1), we find that since Domanico's (2007) assessment the progress has often been slow. Of course there are exceptions, such as Germany, Italy, Spain, the Netherlands and the United Kingdom, representing diverse energy territorialities and landscapes (Table 1). From the inception of the IEM project a small number of national electric utilities dominated the major EU electricity markets (Domanico, 2007; Kolk et al., 2014). Reflecting their energy landscapes and territorialities, the French, German and Italian governments were particularly effective at ensuring that former domestic utilities – at times supported through state sponsored mergers – emerged as sufficiently large stand-alone national champions to survive in the nascent IEM (Kolk et al., 2014). Together with leading utilities in Spain and Sweden, these firms went on to become the 'Seven Brothers' (Thomas, 2003) (see Figure 1). Despite the dominance of these firms, during the almost doubling of total installed generation capacity in just 15 years, the ownership share of their plants' generation capacity has steadily declined across the EU24, from close to 60% in 1990 to around 40% by 2013.

Strikingly, the effective promotion of renewables has simultaneously enabled the emergence of two major decentralized renewable entities, if all independent wind and solar generation assets over 1MW capacity are aggregated (Figure 1). Their shares of ownership as part of the EU24 have increased from 0% in 1990 to 7.7% for wind and 6.1% for solar by 2013. These investors in renewables benefitted from financial subsidies and 'guaranteed and priority access' to the electricity grid and have thus become formidable alternatives to the Seven Brothers. However, the disaggregated nature of this renewable generation capacity has also changed fundamentally the sector's generation ownership structure, increasing the total number of firms in the EU24 from 679 to 2084.

These observations are reflected in the changing compositions of national and regional lists of the ten biggest capacity owners. The most impressive impact is visible in Germany where the original top ten firms in 1996 were all fossil fuel and nuclear energy based utilities but, by 2013, the aggregate number of the developers of (collectively installed capacities) of solar PV and wind power reached 16% in each case, changing them into the two largest 'owners' if treated as one company respectively[4] (see Table 5 and Figure 1). Even across the EU24 countries, the aggregate renewables developers are large enough to take up second and fourth places in the rankings of overall capacity. In a sign of (spatial) convergence (Table 1) in the organization of electricity assets, ten of the 24 countries have at least one form of aggregated renewable energies among their top three generation capacity owners. With the exception of Hungary, Poland and Slovenia, the largest capacity owners in 1996 in all other countries witnessed a reduction in asset concentration by 2013, with the most significant changes occurring in peripheral Ireland, Greece and Italy.

However, overall there has not been a significant and geographically widespread revolution in terms of the ascendance of new owners of pan-European generation assets, which would have systematically taken over ownership shares and lowered the overall concentration level of generation capacity.

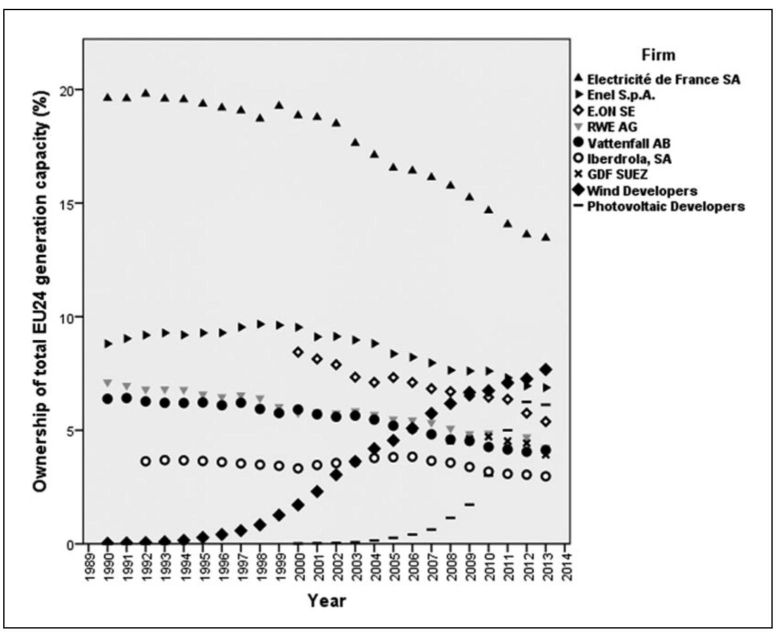

Figure 1. Trends in ownership of European electricity utilities capacity.
Installed generation capacity ownership trends for the largest seven European utilities plus aggregated wind and PV developers (%), 1990–2013. Ownership shares based on 24 countries included in the seven subregional electricity initiatives of the European Regulators Group for Electricity and Gas (ERGEG).
Source: Authors' calculations based on Platts PowerVision data.

Jamasb and Pollitt (2005: 3) argued for the need for '[…] empirically competitive levels (usually thought to occur when the number of effective competitors in a market is at least five)'. Our data suggest that the seven major owners of generation capacity persist across our sample of 24 EUropean countries (Thomas, 2003).

Kolk et al. (2014), however, showed that the Seven Brothers have subregional profiles and have not been able to achieve full regionalization/Europeanization. Equally, we need to point out that, first, Electricité de France stands out as being by far the largest of the 'brothers' (in fact, twice as big as Enel, the second largest); and, second, aggregate sums of wind and solar PV could easily represent two new alternative 'aggregate firms' in this ranking if simply counted as one firm according to generation technology. Moreover, comparing the seven major firms between 1996 and 2013, we find that except for GDF Suez (since 2015 called Engie) the six other utilities witnessed reductions in their capacity ownership shares in our EU24 geoenergy space. This is due partly to their decommissioning of fossil fuel and nuclear plant capacity for political and economic reasons, but also partly because of the significant growth in renewable energy capacities owned by other entities. Consequently, our assessment is that despite a certain degree of enduring dominance by a limited number of very large firms, capacity ownership concentration levels have at least decreased during our period of observation.

Our findings therefore reflect Bouzarovski and Herrero's (2017) observation that 'a single energy transition does not exist across Europe, as the nature of restructuring trends in this sector is contingent upon local and national circumstances', creating spatially differentiated (Table 1) patterns of transition to a dispersed ownership of sustainable EUropean electricity generation capacity at different scales and which we explore in more detail in the following sections.

The potential of subregional (re)scaling of electricity governance

Exploring our results at a subregional scale, we find generally falling rates of concentration of capacity ownership against a trend of increasing levels of renewable electricity capacity installations across the seven EUropean ERI subregions (Figure 2). Across these subregions, renewable generation capacity shares ranged from 22% (FUI) to 46% (Northern), while ownership concentration varies considerably between subgroupings and over time. Within the EUropean energy transition between 1990 and 2013, the sustained and unequal national implementations of market liberalization and promotion of renewables have, interestingly, both led to four distinctive patterns of changing concentration of capacity ownership and investment in renewables, demonstrating the differing energy geographies among groups of ERIs.

First, the smallest Baltic subregion is confirmed as a recognized 'energy island' in Europe (Bouzarovski, 2010; Carstei, 2012). It exhibits some reduction in ownership concentration, but its three member states still feature comparatively high degrees of concentration of ownership, raising doubts about further market integration (Bradshaw, 2013). Advances in promoting renewables are mixed and are set against the decommissioning of nuclear power plant capacity, but the Baltic subregion as a whole compares well with general progress in Europe, with renewables now representing 35% of total installed capacity. While our data do not provide definitive support for specific drivers of these outcomes, both the specific energy landscape and territoriality (Table 1) provide an explanation for this pattern. More importantly, the spatial embeddedness as part of the former Soviet Union's energy system, its geographically peripheral location separating the Baltics, to a large extent, from the 'EU mainland', and the relatively small geographical size continue to create a path dependency (Table 1), which is reflected in the spatial divergence from other subregions (Bouzarovski et al., 2015; Ürge-Vorsatz et al., 2006; Von Hirschhausen and Waelde, 2001).

Second, the FUI and South West subregions have converged on a pattern dominated by a reduction in ownership concentration as the main trend and some progress in renewables investments. However, the extent of change has been limited. The FUI subregion is dominated by France and the UK, the South West by France and Spain. While France has made some contribution to renewable capacity growth, it

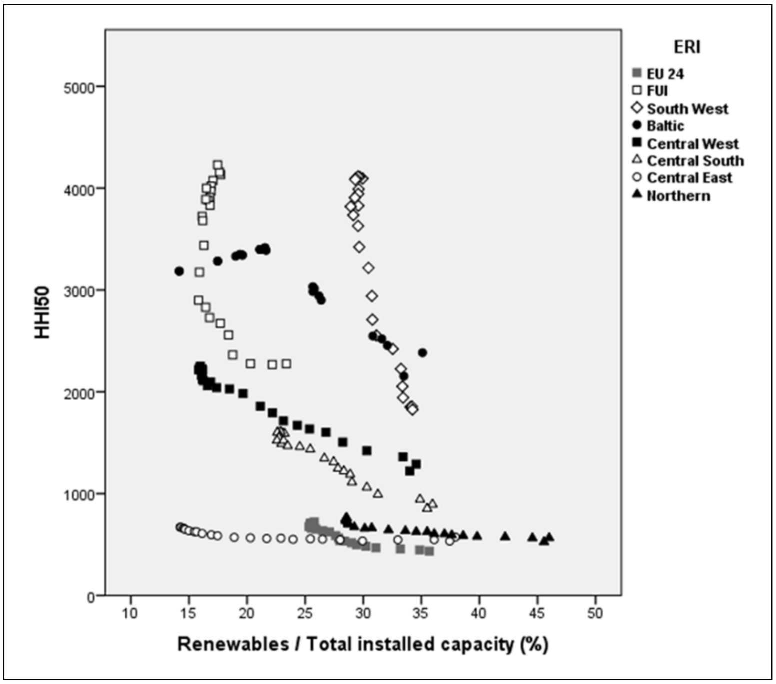

Figure 2. Trends in EU24 subregional ownership and fuel mixes.
European Union subregional electricity generation capacity ownership concentration (HHI50) vs. renewable to total installed electricity capacities ratios (%), 1990–2013. Time series start in upper-left positions.
Source: Authors' calculations based on Platts PowerVision data.

is the respective partner state in each subregion that explains the observed trend. In the FUI, the UK's total capacity has grown by 60% and renewables' capacity more than doubled from a very low base. This has reduced ownership concentration to levels comparable to other leading countries. The territoriality of the FUI subregion is complex, because it includes both the liberal UK (Hall and Soskice, 2001) where renewables are subject to the 'market test' and statist France (Schmidt, 2003, 2009) supporting a nuclear-based path dependency which, it could be argued, explains mixed progress on ownership dispersal and limited progress with regard to renewables. In the South West, Spanish capacity grew by 141%, while maintaining a renewables share of around 38% and significantly reducing concentration of ownership. By contrast, ownership concentration remains very high in France, reflecting the national champion status of the incumbent EDF. The territoriality of the South West, including Spain's enabling state combined with a favourable natural location for renewables, provides one important explanation for the observed progress.

Third, the Central West and Central South subregions have converged, with some progress being made in reducing their subregional ownership concentration, but France's support for EDF continues to affect both subregions. In the Central South subregion, the diverging paths of Italy and Germany provide a counterbalance to the weight of French capacity. Italy's total capacity grew by 145%, while maintaining a renewables ratio of 30%. At the same time, Germany's capacity growth of 74% and renewables capacity ratio of 42% drive the trends in both subregions. The remaining countries have much lower total installed capacity and varying renewables capacity, but both subregions achieve renewables ratios of around 35%. Again the important role of the enabling state in terms of territoriality and, not least, location-specific factors of the respective energy landscapes, providing significant natural resource endowments for renewables, offer important possible explanations for the patterns observed. The combination of the divergent national approaches in subregions improves outcomes, suggesting support for the calls for more poly-centric governance approaches (Goldthau, 2014) to the EUropean sustainability energy transition.

Finally, despite significant increases in renewables capacity, the Central East and Northern subregions experienced few further decreases in the already highly dispersed capacity ownership. Germany dominates the Central East subregion, with more than four times the installed capacity of the next largest country, Poland. Germany equally dominates the Northern subregion, with almost twice the capacity of the next three largest countries by capacity. In both subregions smaller states contribute to the observed trends, but Germany's progress on renewables is central to explaining progress. The degree of ownership concentration and renewables is mixed amongst the smaller states in the Central East subregion (Ürge-Vorsatz et al., 2006), while in the Northern subregion most states have relatively low levels of ownership concentration and good to excellent renewables ratios. Here the greater similarities in the energy landscapes and territoriality (Table 1) of the Nordic countries and Germany explain the dramatic progress of the Northern subregion (Figure 2).

Emerging electricity generation capacity boundaries

We identify in addition two fascinating features from the subregional patterns of changing ownership concentration and renewables adoption. First, while the HHI50 measure of concentration of asset ownership has decreased considerably for the 24 countries studied collectively, both the EU24 and two subregions (Central East and Northern) with the lowest HHI50s have remained at fairly constant levels over the whole period. This suggests the existence of a possible target 'floor' level for the dispersal of capacity ownership which might be achievable for other subregions having more concentrated ownership patterns.

Second, progress with promoting renewables for all but two of the subregions appears to be difficult beyond a 35% share of total capacity. This raises the question of whether this is a structural threshold ('wall') that may require different or new policies. The only two subregions to have surpassed this threshold to a significant extent are Central East and Northern, which both include Germany. The combination of high levels of renewable resource endowments in the Nordic countries, and Germany's 'Energiewende' policy to move to renewables, highlights the possibilities and challenges associated with this transition for the EU and elsewhere. Here, the territoriality of the German state played a central enabling role in negotiating a societally-supported sustainability (energy) transition. It also points at the potential progress to be made by influencing policies in important core countries that are members of more than one subregion through poly-centric approaches to governance (Goldthau, 2014), gaining relative proximity to multiple subregions as a result of their absolute locations in Europe and relative size, and which may help drive wider trends in decreasing electricity generation capacity concentration rates and increasing renewables ratios.

These findings suggest that possible boundary conditions for the emerging future EUropean sustainable energy geographies may already be revealing themselves, reflecting the limits of EUropean natural endowments and the effectiveness of current policy in seeking to enable the EUropean sustainable electricity transition. Here, the concerted role of the German government in enabling the German Energiewende which has, in combination with the natural endowments of the Nordic region, enabled the dramatic progress in the Northern region demonstrates the importance of energy landscapes and territoriality in enabling the transition. Furthermore, the institutional depth of the German policy environment highlights the role of effective policy implementation featured by strong government capacity to enable sustainable energy transitions (Giddens, 2012).

Interaction effects between climate change and liberalization policies

Finally, and significantly, we find that increasing rates of renewable energies are playing a major role in contributing to the energy transition and decreasing rates of asset ownership concentration. In the extreme cases this means that independent renewable energy owners in aggregate are theoretically large enough to exceed a country's biggest utility in terms of installed capacity. In addition, however, where new renewable capacities still remain small, their existence drives up the total number of generators and as such gradually influences the industry ownership structure and wider market dynamics. For example, the high level of renewable penetration in Germany often relies on 'loop-flows' through interconnectors with neighbouring grids to relieve its system in times of oversupply – an issue of political and economic contention (Puka and Szulecki, 2014).

To demonstrate the effect this relationship has on the concentration of ownership of generation capacity over time we correlate the total capacities of renewables against the prevailing ownership of capacity, HHI50, for different countries and regions. The correlation between the two variables is −0.376 and is significant at 0.01(**). This suggests that with increasing levels of total installed renewable energy capacities (regardless of whether this is in a particular country or subregion), we generally observe a decline in rates of concentration of plant ownership as measured by HHI50. Clearly, the widespread dispersion of ownership of renewable capacity has gradually reduced the rates of concentration of capacity ownership of the biggest utilities. This shows that by encouraging new investors and developers (however small and irrespective of fuel type) to enter the market, policy interaction between IEM and renewables directives over time is effectively reducing the dominance of incumbents, as originally intended by the IEM.

We therefore argue that the two different sets of policies with aligned but not explicitly cross-referenced aims and objectives are clearly influencing each other in essentially unintended ways. At the outset at least we find no explicit anticipation in the IEM directives that renewable energy firms would one day enter as serious competitors affecting plant ownership concentration levels from a generation perspective. Rather, a commonly-held belief was that liberalization would actually favour traditional fossil fuelled power assets because of lower financing risks, shorter construction times and better supply characteristics (Jamasb and Pollitt, 2005). In brief, this suggests that each Directorate was pursuing its own separate agenda without any explicit consideration of potential unintended consequences.

Over time this has led to a situation in which large amounts of renewables are increasingly competing for capital funds with established utilities (with significant financial implications). Because of their low marginal costs and preferential grid access treatment (afforded to them through the IEM Directives), renewable energies are now effectively driving far-reaching changes in the industry's ownership structures.

Policy implications and future research

We have responded to calls for research on sustainability energy transitions as spatially-constituted phenomena. Studying the changes in fuel mixes and generation capacity ownership across EU, subregional and country level scales, we find that progress in terms of creating a single energy market, while addressing climate change as fostered by EU and member state energy policies, remains slow, but significant improvements are occurring. More importantly, we find that the energy geography concepts of location, territoriality, landscape and spatial embeddedness are valuable tools in terms of interpreting the emergent features of (re)scaling and spatial differentiation (Table 1), and help explain the evolution of the concentration of energy asset ownership (Bridge et al., 2013). In particular, location-specific natural resource endowments, territoriality reflecting varying levels of institutional thickness and capacity, and embeddedness in specific historical path dependencies and geographical landscapes continue to exert strong forces on energy asset investment, which either align with or counteract EU policies and thus lead to diverging patterns of transition.

Interestingly, by re-scaling to subregional level we find that the divergence in findings identified at the national scale and the relative convergence at the EUropean scale resolve into four clear patterns of transition. Although concentration levels of asset ownership remain high in many countries, they are significantly lower if re-scaled to a subregional scale. In fact, the most dramatic improvements appear to be happening at a subregional scale. Stated differently, while policy aims and directives may have been specified at EU or national levels, the actual focal point and enabler of these outcomes appears to be the subregional level. Naturally, major differences remain in terms of geographical, economic and political conditions (not least because subregions contain different numbers of countries of varying sizes, with different economic and political characteristics). In fact, the notion of re-scaling of macro-regional approaches is itself controversial (e.g. Bialasiewicz et al., 2013), but broadly we believe that through regulatory integration at subregional levels greater harmonization is occurring. The diversity in the national territorialities and energy landscapes benefits from a balancing out of the national scale 'extremes' at the subregional scale, leading to greater overall degrees of progress. To that end, our findings extend Jamasb and Pollitt's (2005: 37) prediction that 'the most plausible route to a single European market is through [sub]regional markets as an intermediate stage'. Because some countries are simultaneously part of several subregions, we surmise it is perhaps exactly this geographical linkage and overlap between different subregional territories which seems to serve as the key driving force of convergence. The European Commission's (2015) argument that '[sub]regional approaches to market integration are an important part of the move towards a fully integrated EU-wide energy market', is thus to be welcomed as a policy that recognizes the potential for analysing and addressing better the energy transition challenges of the EU. At the same time, while the subregional scale reveals the emerging boundaries to the EUropean electricity sector sustainability transition in terms of ownership dispersal and promotion of the capacity of renewables, the role of member states in transposing and facilitating EU legislation remains a critical influence on progress with both dimensions.

We also provide in this present paper empirical evidence of how renewable energies benefitted from the IEM directives by enabling their growth and providing them with access to the market. Our results support the argument that, somewhat unwittingly, IEM directives, and climate change directives essentially directly, have encouraged and enabled greater numbers of firms that mostly invest in renewable energies for their national and subregional markets. In other words, while IEM directives appear not to have been the key driving force behind falling rates of concentration of capacity ownership (although they have substantially facilitated this trend), improvements in the general dispersion of ownership on the generation side have resulted from the EU's climate change policies and, in particular, support for renewable energies. As a consequence, increasing levels of renewable energy capacities are not owned by the incumbents and this has led to slowly but broadly decreasing ownership concentration rates.

Of course, such developments are not uniform across all countries and much relies upon national legislation to provide dedicated economic and technical support. We argue, however, that changing fuel mixes and greater diversity of ownership at the generation level are interdependent. The potential for unintended outcomes due to policy-making and implementation has long been recognised (Wildavsky, 1979) and thus the initially parallel, largely isolated development of the EU internal energy market and climate change policies explains the central role of renewable electricity technologies in changing the structure of the EU electricity sector. The evolution of the electricity sector is thus argued to be an unintended desirable outcome of policy interaction (Merton, 1936).

However, our subregional lens does not provide additional insights into the identified unintended interaction of the EUropean IEM and RES policies as implemented at national scale, reflecting the current lack of subregional territoriality with sufficient institutional depth and capacity to lead the further drive for policy implementation. This suggests that greater support for strengthening subregional institutions in the EUropean electricity sector is needed in order to accelerate the sustainability transition.

Our research is bounded by specific limitations, which offer potential avenues for future development and extension. For example, there are questions about the validity of and insights gained from using the HHI, particularly for predicting market power in the electricity sector (e.g. Borenstein et al., 1999; Swinand et al., 2010). Because we neither attempted to make predictions nor sought to estimate impacts on wholesale prices, we believe this measure provides a widely accepted and satisfactory assessment of the concentration levels of asset ownership regarding generation capacity and remains in keeping with previous research (e.g. Jamasb and Pollitt, 2005; Percebois, 2008). Future research may however seek to draw on alternative measures of, and data for, asset concentration. Because we were interested in changing levels of ownership on the power generation side as well as changes in countries' fuel mixes we did not – and could not – assess changes in retail markets. In addition, the limitations of our data do not provide us with the opportunity to investigate changes in vertical integration (e.g. through acquisitions or sale of transmission and distribution assets) or horizontal diversification (e.g. entering gas supply markets). Finally, as noted earlier, future research also should study the effects of the sustainable energy transition by assessing the changes in terms of actual electricity supplied. The highly intermittent nature of increasing amounts of renewable energy capacities is creating new operational challenges that demand greater wholesale market pricing flexibility, grid interconnection and regulatory interdependence. All of these aspects may provide further fruitful research opportunities on energy geographies.

To conclude, our research has explored changes in the EUropean electricity sector by drawing on the emerging literatures on energy geographies. Our empirical results suggest that concepts proposed by Bridge et al. (2013) enable deeper insights into the spatiality of energy transitions. Specifically, we find that territoriality and scaling (Table 1) are key lenses for interpreting the differentiated change processes occurring at EU, subregional and national levels. The EUropean energy transition is unlikely to converge onto a single trajectory in the near future, but we would argue that subregional approaches in particular, such as through strengthening the existing ERIs, offer policy-makers more spatially-cognizant and effective levers.

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Notes

1. For more information, see: http://www.platts.com/products/powervision.
2. For further information, see: http://www.ceer.eu/portal/page/portal/EER_HOME/EER_ACTIVITIES/EER_INITIATIVES/ERI and http://www.acer.europa.eu/Electricity/Regional_initiatives/Pages/default.aspx.
3. Membership of EU15+2 (July 2016): Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom; plus Norway and Switzerland.
4. These figures do not include renewable assets owned by the major utilities themselves.

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