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Varieties of clean energy transitions in Europe

Political-economic foundations of onshore and offshore wind development

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Abstract: The paper introduces a novel framework for classifying different types of national political economies. It applies the outlined framework to analyse in an historical perspective the development of one mature renewable energy sector (onshore wind) and one infant renewable energy sector (offshore wind) across three major types of European economies. The paper shows that the presence of strategic state–market coordination and the decentralized pluralist polity constitute key enabling factors that drive the development of new renewable energy technologies. The commonalities and differences in the political economy of the onshore and offshore wind sectors are also discussed.

Keywords: onshore wind, offshore wind, green industrial development, energy transition, varieties of capitalism
JEL classification: O25, O38, O33

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1 Introduction

The collapse of the global financial system in 2008 and the persistently slow economic recovery ever since have prompted a renewed interest in industrial policy and a more active role of the state in spurring on economic growth (European Commission 2014). The promotion of green sectors, including renewable energy sources, as an engine of economic growth has become particularly attractive given the increasing maturity of green technologies and the growing consensus about the urgency of environmental problems (Rodrick 2013). The European Union (EU) has long been a front-runner in setting ambitious targets and formulating policies for advancing new green technologies and decarbonizing the economy. Similar to the industrial policy field, however, the common EU energy policy in general and renewable energy policy in particular, face major implementation and legitimacy challenges (Szulecki and Westphal 2014). The EU renewable energy directive from 2009, which introduced obligatory national renewable energy targets, has largely been successful in accelerating the uptake of renewable energy policies and technologies in most, if not all, member states and accession countries. The hard-fought negotiations over the new directive, which resulted in a less ambitious overall EU renewable energy goal without specific national targets, have brought to the surface the divergent interests and narratives among EU states concerning the greater deployment of renewable energy sources. The national disagreements within the EU over the necessity and the design of renewable energy policy are exemplary of common lines of conflicts and barriers to clean energy transition on a global level. This paper seeks to illuminate how the sources of the divergent national approaches to the promotion of new renewable energy technologies are tied to their inherited political-economic structures.

There is a broad consensus among scholars and practitioners that a wide range of new renewable energy technologies must be standardized and become cost-effective if energy systems are to be decarbonized and excessive climate change avoided (Verbong and Loorbach 2012). The question remains, however, as to the motives and capacities of different national economies to advance new technologies 'to the shelf' and adopt the already advanced technologies 'from the shelf' (Sandén and Azar 2005). An extensive body of literature has emerged, particularly within the studies on sustainability transitions (Smith and Raven 2012; Kern et al. 2014) and national innovation systems (Suurs and Hekkert 2009), seeking to understand how and why renewable energy innovations develop in a certain context and what factors determine their successful diffusion to other institutional settings. The major shortcoming of the existing literature is that national political-economic institutions and interests and processes which underpin them have often been neglected or discussed in a non-systemic manner based on stand-alone national case studies. In addressing this gap, a recent trend in studying green industrial policies in general and sustainable energy policies in particular, has been to identify common trends across countries and explain them in relation to the particular type of national political-economic 'logic'. The underlying questions that lie at the core of this approach are: Are there commonalities in national clean energy transition pathways, can they be attributed to the specific type of national political-economic setting and what implications does this have for understanding the past, present, and future of clean energy transitions? The framework of Varieties of Capitalism (VoC) (Hall and Soskice 2001) has been suggested as a promising approach for capturing and investigating the common types of national market economies and how they influence technology and policy choices and steer the direction and pace of energy transitions (Ćetković and Buzogány, 2016). Furthermore, several studies have suggested that some varieties of capitalism are more conducive to developing and exporting sustainable energy technologies than others (Mikler and Harrison 2012; Ćetković and Buzogány 2016).

This paper seeks to contribute to the literature which adopts the comparative capitalism approach to clean energy transitions in two respects. First, it develops further the theoretical rational for applying the VoC framework to understand and compare national renewable energy transition pathways. It does so by bringing back the state in the analysis and enriching the VoC framework with the literature on national innovation systems, state–industry relations and corporatism vs. pluralism debate. In addition, the paper extends the so-far applied categorization based on the distinction between Liberal Market Economies and Coordinated Market Economies, by including a largely neglected type of what we termed 'simple Coordinated Market Economies'. Second, the paper demonstrates the value of the proposed conceptual framework by exploring the fate of two related renewable energy technologies which are at the different stage of development: one mature renewable energy technology (onshore wind) and one infant renewable energy technology (offshore wind). Both onshore and offshore wind are seen as central technologies for achieving a clean energy transition. This should allow for discerning the relative importance of national vs. sector-specific features in influencing the diffusion of new renewable energy technologies. The historical investigation of two renewable energy sectors in different forms of national economies will also reveal important lessons about the cross-national linkages as well as cross-sectoral dynamics when it comes to renewable energy transition. Although the study draws on the experience from European economies, it argues that the proposed framework and the lessons learned are relevant for explaining renewable energy policies in other market economies.

2 Theoretical and methodological framework

Our starting point for analysing and comparing how different national political-economic structures can influence national renewable energy transitions is comparative research that emphasizes the role of state–industry–society–science relations as drivers of sectoral innovation and policy change. We draw here mainly on the 'varieties of capitalism' perspective in comparative political economy that emphasizes the institutional differences among developed capitalist market economies (Hall and Soskice 2001; Hancké et al. 2008; Hall and Thelen 2009; Hall and Gingerich 2009). These differences between capitalist economies concern mainly the question of how the political institutional context helps or hinders firms to solve their cooperation problems. The main focus of the approach is on firms and the institutional setting they are embedded into. Five institutional spheres are singled out as being particularly relevant: 1) industrial relations and wage bargaining; 2) vocational training and education; 3) corporate governance and returns on investments; 4) inter-firm relations; and 5) intra-firm relations. According to Hall and Soskice (2001), based on these five spheres, most developed market economies cluster into two distinct types of capitalism, which they call 'Coordinated market economy' (CME) and 'Liberal market economy' (LME). Germany, Austria, and the North European countries are considered to be the archetypal CME countries, whereas Anglo-Saxon states United Kingdom (UK), United States (US), or Ireland are those described as LMEs.

These distinctions between VoCs (see Table 1) are important because they enable the systematic identification of different characteristics and likely problems that occur in LMEs or DMEs when firms innovate. According to Hall and Soskice, LMEs favour radical, path-breaking innovation processes and hold comparative advantages in innovation-intensive high-tech industries and services (Hall and Soskice 2001: 40–41). Innovation in CMEs is mainly taking place in traditional industry fields, such as machinery or chemical production. In contrast to LMEs, innovation in CME countries is rather small-scale, incremental, but also more continuous. It is often based on path-dependent cooperation between firms and the banking sector as well as science. In general, long-term perspectives dominate over concerns of immediate profitability, a feature that is found to be typical of LMEs. The path-dependent innovation process in CMEs is not necessarily by choice but to a large extent structurally predetermined: industrial relations in CMEs are typically more oriented towards employee participation, trade unions have a stronger say, and labour law gives less chances for hiring and firing. At the same time, long-term contracts provide employees with longer incubation periods and the security to experiment with innovation without the risk of being fired in case of lacking success. This innovation path is supported also by the system of vocational training, which emphasizes interactions between industry and research and is able to produce highly skilled workforce.

Table 1: Overview of the VoC approach

	LME	CME
Industrial relations and wage bargaining	Low unionization density Firm level bargaining	High unionization density Industry-level bargaining
Vocational training	General skills	Industry-specific skills
Corporate governance	Short-term capital (stock market)	Patient capital
Inter-firm relations	Competitive	Collaborative
Intra-firm relations	Adversarial	Collaborative
Innovation	Radical	Incremental

Source: Authors' illustration based on Hall and Soskice 2001.

While the VoC framework has been mostly used to explain differences between 'old' industrial production and rise of 'new' technologies, it also lends itself to analyse clean energy transitions and innovation paths. Several analyses of political and economic systems suggest that states with more consensual structures produce better environmental output (Scruggs 2001, 2003; Mikler 2009; Kern 2011; Menzel and Kammer 2012; Lachapelle and Paterson 2013). In contrast, recent research shows that LMEs are often caught in the structural 'trap of radical innovation' (Mikler and Harrison 2012; Harrisson and Mikler 2014). Thus, the inherent focus on short-term returns on investments in LMEs does systematically hinder them in pioneering clean energy transitions. As Mikler and Harrison (2012) argue, the increasing successes in climate change mitigation that the LMEs have recently seen in some sectors were, paradoxically, the result of their turn towards more coordination and a state-led 'developmental' approach and not of LME style radical innovation (MacNeil 2012; Ćetković and Buzogány 2016).

Such findings are echoed by the larger literature that focuses on the 'entrepreneurial state' (Mazzucato 2015) and point towards a weak spot in VoC's theory of innovation (Taylor 2004; Akkermans et al. 2009). By focusing on firms and sector level innovation, the VoC framework disregards the role of national institutions, which often play a central role in financing research and development budgets, supporting universities, and encouraging the creation of new markets or the diffusion of new technologies. Emphasizing institutional stability rather than change, the VoC framework is criticized for being static and deterministic in character (Hancké 2009). This makes change occurring within and across VoCs difficult to capture analytically. However, in this paper we show that refining and fine-tuning the VoC framework can provide us with an analytical, useful tool for analysing clean energy transitions. We complement the VoC framework with insights from the literature on national innovation systems on the one hand, and on comparative political science literature differentiating state–industry–society relations on the other hand.

The literature on national innovation systems suggests that the linear model of innovation provides an inadequate picture of how technology innovations in different economic fields emerge and become widespread (Bergek et al. 2015). This particularly holds true for new renewable energy technologies. Although the provision of new knowledge through research and development (R&D) spending ('push mechanism') is critical for developing and improving renewable energy technologies (Ragwitz and Miola 2005), their market success is contingent on a number of additional factors. These factors are often described as 'pull mechanism' and should serve to facilitate market formation for new technologies. Whereas for some innovations the market demand is easily facilitated through marketing and product-placement activities, new energy technologies face much stronger structural and institutional barriers and thus require more complex and targeted support. This includes the existence of 'niches' where new technological innovations can incubate (Smith and Raven 2012; Raven et al. 2015). It also includes the creation of stable and long-term market demand, provision of necessary skills for developing and operating new technologies, financing, and supportive legal conditions (Fagerberg 2015). One should also add the necessity of legitimization for new technologies (Jacobsson and Bergek 2004). Still, the key driver in capitalist economies is profit generation and capital accumulation. This implies that those political-economic systems that are capable of promoting industrial competitiveness and more widely distributed economic gains from renewable energy sources are likely to be the most ambitious ones in supporting infant renewable energy sectors and innovations.

The second relevant literature, focusing on neo-corporatism, welfare states, and political systems in Western Europe emphasizes this later point concerning the collective redistribution of economic gains on a broader basis (Lehmbruch and Schmitter 1979; Esping-Andersen 1990; Lijphart 1999). Arguably, this literature, rooted in comparative political science and political economy, can be seen as the main field of research which has informed the development of the VoC framework. There are important affinities between Lijphart's classification of political systems as majoritarian vs. consensus-oriented and the VoC framework's LME vs. CME typology: '[…] consensus political systems are almost co-extensive with Coordinated Market Economies, just as majoritarian political systems are almost co-extensive with liberal market economies' (Schneider and Soskice 2009). Focusing on the emergence of these different types of welfare states and/or varieties of capitalism, comparatists argue that historical choices of electoral systems are at the core of the assessed differences (Martin and Swank 2008; Cusack et al. 2007). Schneider and Soskice (2009) argue that while majoritarian political systems have a centre-right bias that leads to low propensity of redistribution, political systems with proportional representation favour centre-left coalitions which are more egalitarian in income distribution. At the same time, the choice of electoral system has implications also for the number of parties: according to 'Duverger's Law', which asserts that electoral systems with proportional representation tend to favour plural party systems, whereas majoritarian systems lead to two-party systems. Taking into account Colomer's observation that the number of parties significantly and systematically increases policy stability (Colomer 2012), we can summarize that LMEs can be typically found in two party-systems with high levels of policy instability, whereas CMEs usually have multi-party systems and feature higher levels of policy continuity. Thus, institutional and party system factors can help explain the long-term and stable support for certain policy issues or the lack of it. While these factors help us to understand an important part of the political dynamic in CMEs and LMEs, the literature on comparative capitalism that has emerged following Hall and Soskice's framework has pointed out repeatedly that the existing LME–CME dichotomy does not fit neatly for several political economies, not even in Europe (Schmidt 2003; Campbell and Pedersen 2007; Nölke and Vliegenthart 2009; Bohle and Greskovits 2012; Ornston 2012).

One possibility for further differentiatiating the political institutional context has been suggested by Vivian Schmidt who takes a polity-oriented perspective on European political systems (Schmidt 2005, 2012). According to her, the effects of institutional arrangements can be conceptualized as being 'simple' and 'compound' polities. Whereas in simple polities the state structure is centralized and governing is concentrated in a single authority, compound polities feature multiple authorities. Drawing on these insights, we distinguish between simple and compound varieties of capitalism. As Table 2 illustrates, the UK is an example of a simple polity, whereas the US and Germany, which are both federal states, are compound polities. The Scandinavian states are simple polities as they have unitary states. At the same time, they also feature a political culture that emphasizes strategic coordination and consensual decision-making.

Table 2: Varieties of capitalist market economies in simple and compound polities

	LME	CME
Simple	United Kingdom	Sweden Netherlands Norway Denmark
Compound	(United States)	Germany

Source: Authors' illustration based on Hall and Soskice 2001 and Schmidt 2012: 107.

Simple LMEs can be seen as being flexible innovative economies that rely on a limited state role, competition, and market demand. The majoritarian representation results in a two-party system, and, in most cases, in a single party government. The uptake of new, alternative innovations, that potentially challenge the sectoral status quo, is complicated by two factors: higher levels of policy instability and the limited number of issues that can be discussed in the political arena. In addition, in simple LME, (and in contrast to compound LMEs, such as the US) the centralized structure of the polity can preclude bottom-up development and experimentation which is often necessary for green energy innovations to mature and gain broader support.

Simple CMEs, in turn, are characterized by proportional representation, multi-party systems, strategic coordination and unitary consensus-based political systems. While this might be seen as conducive to the adoption and successful promotion of innovations, the polity structure and interwoven corporatist relations between industry, labour, and the state can in fact hinder, or at least inhibit, more radical innovation processes if these endanger the positions of well-established stakeholders. It is also important to note that CMEs are small, open economies which are highly dependent upon, and responsive to, broader regional and global impulses.

Finally, *compound CMEs*, such as Germany, share several features with simple CMEs. They are characterized by multi-party competition and are oriented towards strategic coordination and consensual decision-making. Mechanisms for coordinating the state–industry–labour–science relationship are in place but given the compound polity and the disruptions caused by competitive party system, the political process is more dynamic and allows for the plurality of multiple ideas and voices, also at different levels of government.

Based on the theoretical discussion above, we can now hypothesize how different national political-economic structures influence sectoral innovations. We restrict our focus to West European states across three subtypes of capitalist market economies: Simple LMEs (the UK), Simple CMEs (Nordic countries, Netherlands), and compound CMEs (Germany). The case selection of countries is influenced by the fact that they all have significant onshore and offshore wind potential. Using process-tracing techniques, we take a long-term perspective of sectoral developments as we aim to describe and capture changes that have occurred over several years. We look at several indicators of wind industry performance (number of patents, R&D spending, job creation, industrial competitiveness, installed capacity) and explore their relation to the type of national political-economic setting. In doing so, we rely on secondary analysis of existing studies and reports, as well as government documents.

We make two central assumptions. First, due to the mechanism of strategic coordination and consensus-based policy style, both simple and compound CMEs are more conducive to exploring economic opportunities through strategically advancing new renewable energy technologies, in this case onshore and offshore wind, than LMEs. Second, as already noted, emerging renewable energy technologies require sufficiently plural environments in which they can grow and mobilize political support. This implies that compound CMEs are more open than simple CMEs to experimenting with and embracing new energy technologies

In the following sections we provide evidence on how differences in state–market relations and the structure of the polity influence innovations and industrial upgrading in the wind energy sector.

3 Empirical analysis

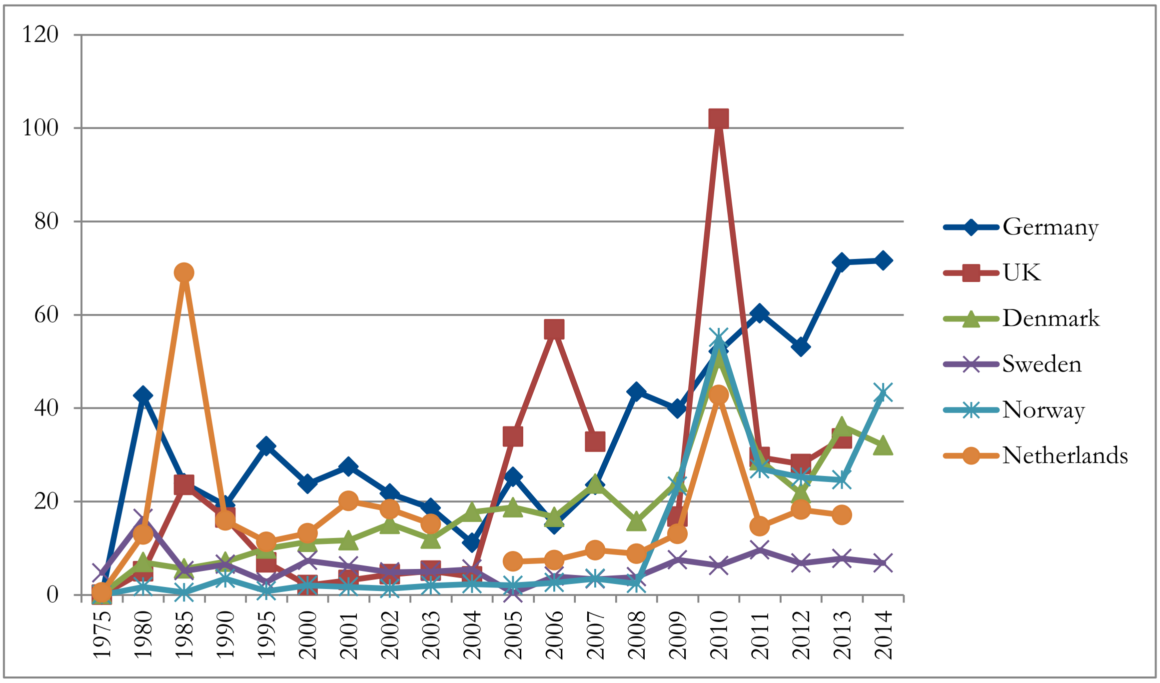
3.1 Onshore wind

Compound CME (Germany)

Similar to many other industrialized countries, the first government measures for supporting renewable energy sources in Germany can be traced back to the mid-1970s, in response to the oil crises in 1973 and 1979 (Lauber and Metz 2004; IRENA 2012: 64). However, while many other countries were quick to curb their enthusiasm for alternative energy sources once the oil prices stabilized, the support for renewable energy in Germany had a more solid base. The nuclear accident in Chernobyl of 1986 and increasing awareness of climate change were instrumental in strengthening the positive public attitude in Germany towards alternative and more sustainable energy sources and encouraging more concerted policy support for renewable energy technologies (Jacobsson and Lauber 2006: 264). Wind power played a central role in renewable energy development in Germany from the very beginning. Initially, the wind energy enthusiasts experimented with small-size turbines for local use while the national government directed support towards large-scale wind power plants, most notably the *Growian* project launched in 1980 (Bruns et al 2011: 265). Eventually, the government-funded R&D programmes encompassed a variety of wind turbine models, from small to large installations, supplied dominantly by German manufacturers (Jacobsson and Lauber 2006: 263). In 1989, the government began supporting market creation by subsidizing 100 MW of wind power which in 1991 extended to 250 MW (Lauber and Metz 2004: 201). The first Electricity Feed-in Law adopted in 1991 laid the ground for rapid market expansion of wind power by introducing fixed preferential tariffs (Feed-in Tariff—FiT) for electricity produced by renewable energy sources. This was accompanied by several supporting programmes for research, demonstration, and project implementation enacted by the national government as well as the governments of some federal states (Lauber and Metz 2004). The new Renewable Energy Law of 2000 further improved the overall framework for renewable energy sources by guaranteeing fixed technology-specific tariffs for renewable energy producers for the period over 20 years. In 2010, the government adopted the Energy Concept which stressed renewable energy as a cornerstone of the future energy mix and set the target of 80 per cent renewable energy in the electricity mix by 2050 (BMWI/BMU 2010). The nuclear accident in Fukushima in 2011 marked another major turning point which led to the nation-wide consensus on phasing-out nuclear energy and transitioning towards renewable energy sources (Jahn and Korolczuk 2012). The Renewable Energy Law has been amended on several occasions, most recently in 2012 and 2014. Although the fundamentals of the support scheme which relies on price-based incentives have largely remained intact, the regulatory adjustments in 2014 entailed two important changes. First, obligatory direct marketing with a floating premium price is introduced for newly installed renewable energy capacities of more than 500 kw second. The law for the first time defines the annual expansion limits for different technologies, which for onshore wind power includes 2.5

GW of annual growth (Bundestag 2014). These measures are designed to ensure better planning and more efficient integration of renewable electricity into the market. The Renewable Energy Law of 2014 also specifies long-term goals for the share of renewable energy in gross electricity consumption (40 to 45 per cent by 2020, 55 to 60 per cent by 2035 and 80 per cent by 2050) (Bundestag 2014). The R&D spending on wind energy has been consistently high, both from the public and corporate sources (European Commission 2013: 38-39) (See Figure 1).

Figure 1: Wind energy total RD&D in million US$ (2014 prices and exchange rates)



Source: OECD (2015a).

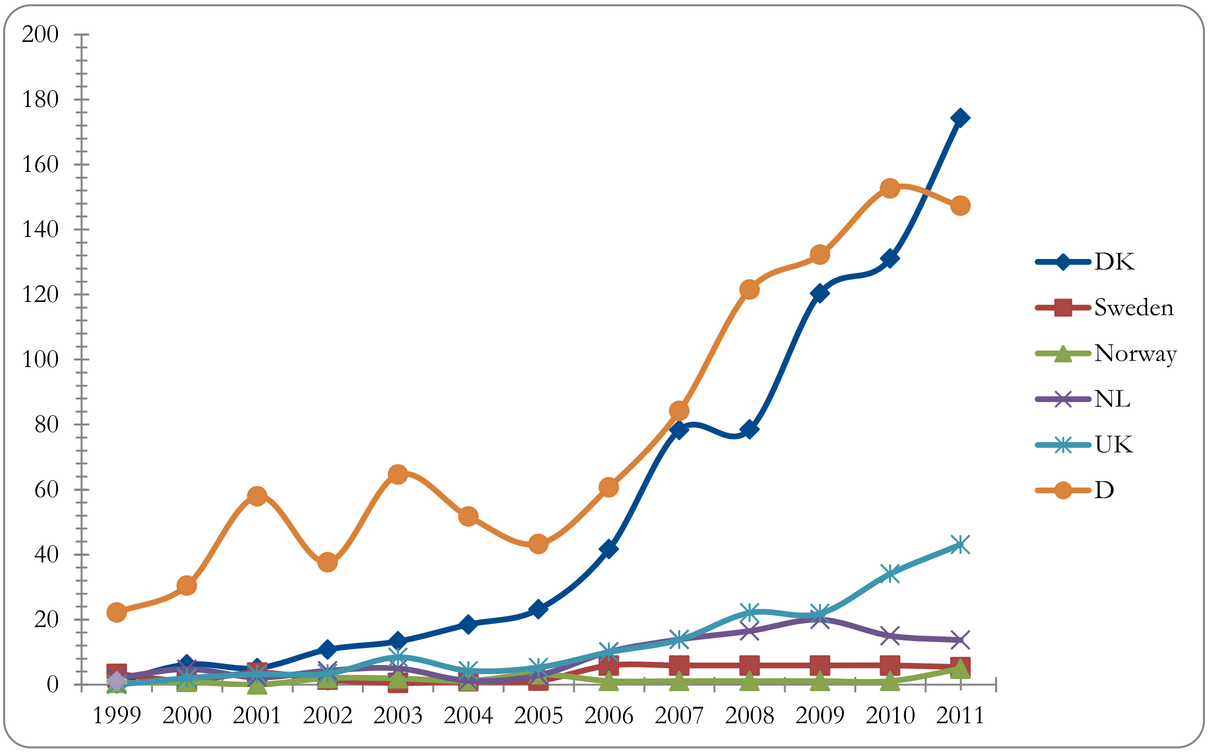
As a result of implemented policy, the growth of onshore wind installations in Germany has witnessed a continuous annual increase ever since the early 1990s (IWES n.d.). Despite regulatory changes, Germany added 3.5 GW of onshore wind power in 2015, the second largest annual net increase following the year 2014 (BWE 2016). In total, at the end of 2015, Germany had as much as 41.6 GW of the installed onshore wind power (BWE 2016) (see Table 3). Not only has the German policy approach been effective in creating a vibrant domestic market for wind energy, but it has also significantly enhanced industrial competitiveness, innovations, job creation, and environmental benefits (Pegels and Lütkenhors 2014; Ćetković and Buzogány 2016) (see Table 3 and Figure 2).

Table 3: Installed capacity and jobs created in onshore and offshore wind

	Operational Onshore GW (2015)	Operational Offshore GW (2015)	Direct Jobs (Onshore and Offshore)
Germany	41,6	3,3	117,900 (2012)
UK	8,5	5	15,500 (2015)
Denmark	3,8	1,3	29,000 (2015)
Sweden	5,8	0,2	N/A
Norway	0,8	0,02	N/A
Netherlands	3	0,4	2,150 (*only offshore*)

Source: Adapted from EWEA (2016a, 2016b); GTAI (2014); RenewableUK (2015b); Ecofys (2014).

Figure 2: Wind energy patents



Source: OECD (2015b).

The German wind energy sector consists of a wide network of turbine manufacturers and suppliers and constitutes one of the most competitive wind energy industries globally (Boeckle et al. 2010). The German company Enercon grew to become the major supplier of onshore wind turbines to the domestic market with 43.1 per cent of the market share (Windpowermonthly 2015). Based on the data from 2012, the wind industry in Germany employs 117,900 people, out of which 18,000 are in offshore wind (GTAI 2014: 7). All this signifies remarkable policy stability and overall policy success. It would be wrong to conclude, however, that renewable energy policy in Germany has not faced manifold challenges, opposition, and setbacks during the past almost three decades. In fact, it is through the political contestations and 'battle over institutions' (Jacobsson and Lauber 2006) that the emergence of the renewable energy sector in general, and wind energy in particular, was made possible. The pluralist and federal political landscape allowed the early wind energy advocates among political, industrial, farmer, labour, scientific, and civil society actors to experiment with wind energy technologies, attract the attention of policy-makers at different levels of governance (local, federal, national), and mobilize support for the government promotion of wind power. The fact that new renewable energy sectors were initially not perceived as a significant threat to the established energy utilities and conventional policy paradigm only facilitated further the acceptance of the government support for wind and other emerging renewable energy technologies. Once wind energy became more widely embraced and it began producing economic gains for both citizens and the industry, the legitimacy of wind energy became increasingly difficult to dispute. Jacobsson and Lauber (2006) illustrate well how the alliance of wind energy supporters from different spheres of politics and society successfully persuaded, on several occasions, parliament members to refrain from reducing wind energy subsidies. This was particularly critical in the formative phase of wind energy development during the 1990s. The goals of industrial modernization and job creation from wind energy resonated well not only with the green and leftist political agenda but also with the interests of some conservative political elites. Jacobsson and Lauber (2006: 265) cite one member of the Christian-Democratic Party and director of a wind turbine manufacturer who stated: 'In this matter, we collaborate with both the Greens and the Communists'. As the wind energy industry matured, it was able to benefit from the already present mechanisms of strategic state–market interaction and industrial upgrading in Germany, typical for CMEs. This included long-term technology-specific government support, export promotion, vocational training, local and national financing instruments, and close science–industry collaboration in the area of research and development (Ćetković and Buzogány 2016). One should also add the ability of the German government to diffuse renewable energy goals to the EU and international level and so enlarge the market for German wind energy technology (Cox and Dekanozishvili 2015). Overall, Germany has developed a comprehensive, almost a textbook-like, 'push and pull' policy strategy for championing wind energy. From the discussion above, it can be said that the pluralist political environment has launched wind energy on the political agenda whereas the strategic and locally embedded state–market interactions strengthened the legitimacy of wind energy and turned it into a successful industrial policy.

Simple LME (UK)

The UK has the largest technical potential in onshore wind energy among all EU countries (EEA 2009: 21). The deployment of this potential and creation of local value-added in terms of new jobs and industrial upgrading have been, however, unstable and confronted with manifold challenges. The government began supporting research on wind energy in the mid-1970s. Whereas the basic research and education on wind energy has been assessed as good, there has been limited collaboration and networking among scientific institutions as well as between science and industry (Simmie et al. 2014). The key obstacle to the growth of the wind energy sector and domestic wind power technologies has been the lack of a credible and long-term pull mechanism from the government that would facilitate market formation.

In 2000, the government announced plans for achieving 10 per cent of electricity from renewable energy sources by 2010 'as long as the cost to consumers is acceptable' (DTI 2003: 45). In 2009, the EU set the target for the UK of 15 per cent of energy from renewable sources by 2020 (Directive 2009/28/EC 2009). The development of both onshore and offshore wind is essential for achieving the national target (DECC 2011: 14). The government support for renewable energy evolved from technology-neutral support schemes, embodied in the Non-Fossil Fuel Obligation (NFFO) of 1989 and Renewables Obligation (RO) of 2002, to the more technology-specific RO model adopted in 2009 and FiT for small renewable energy plants of less than 5 MW introduced in 2010 (Simmie et al. 2014; Ćetković and Buzogány 2016). In 2013, the government enacted the Electricity Market Reform under the new Energy Act which foresees a gradual replacement of the RO model with the market-based support scheme called Contracts for Difference (CfD) by 2017. CfD is based on the *strike price* defined through an open auctioning procedure. If the market price is lower than the strike price, the power generators are compensated for the difference. The government sets and adjusts the overall budget available for CfD. It is also worth noting that CfD targets not only renewable energy technologies but also nuclear and carbon capture and storage. Although RO was planned to last until 2017, the government recently announced the decision to close RO for onshore wind already in 2016. It has even been suggested that onshore wind will be removed from future auctions under the CfD scheme implying the end of subsidies for onshore wind projects (Howard and Drayson 2015: 8). These government plans have faced fierce criticism from the wind energy industry (Vaughan 2015). Other regulatory changes have further reduced the profitability of renewable energy projects, such as the decision in 2015 to remove the exemption from the climate change levy for electricity from renewable sources (HM Revenue and Customs 2015). Alongside considerable policy uncertainty, long and cumbersome administrative procedures have posed further barriers to onshore wind development. The planning process and issuing of permits for onshore wind energy in the UK are often cited as being among the longest in the EU (IRENA 2012: 130). In addition, the UK planning guidance imposes the limit of the onshore wind turbine tip-height to 125m. This is much stricter than in other countries and precludes the possibility of installing new, larger, and more efficient wind turbines (RenewableUK 2015a: 11).

The first commercial onshore wind farm in the UK was built in 1991. However, the deployment of wind energy on the land was relatively slow during the 1990s. For instance, in 2000 the UK had 406 MW of installed wind power capacity, compared to as much as 6,113 MW in Germany (GENI 2001). The real progress occurred in the second half of the 2000s as a result of a more supportive national policy context and adoption of the EU Renewable Energy Directive in 2009. As a result, in 2010, the R&D investments in wind energy reached the highest level (see Figure 1). The largest share of R&D spending on wind energy in the UK, however, was performed by the state rather than by corporate actors (European Commission 2013: 38-39). 2012 was the record year in terms of the annually installed onshore wind capacity with 1,937 MW of onshore wind power being connected to the grid (RenewableUK 2014: 19). In 2013 and 2014 the overall onshore wind capacity continued to increase but at a slower pace (RenewableUK 2014:19). The overall installed capacity in 2015 was 8.5 GW (RenewableUK 2016) (see Table 3). The UK domestic wind energy industry has struggled to develop (IRENA 2012: 130). In terms of job creation, the figures from 2015 estimate that the number of workers directly employed in the wind industry in the UK was 15,500 (RenewableUK 2015b: 3) (see Table 3). The number of registered patents has also been considerably lower than in Germany and Denmark (see Figure 2).

The centralization of political power and insufficient state–market coordination have decisively constrained the market and industrial expansion of onshore wind in the UK. The unitary state structure and majoritarian political system have failed to provide policy certainty and have offered little space for wind energy stakeholders to win the hearts and minds of decision makers and the local population. None of the two leading political forces, the Labour Party and the Conservative Party, have demonstrated a commitment to promoting onshore wind energy. The space for bottom-up initiatives has been limited due to the unitary state structure and centralized, oligopolistic energy system (Simmie et al. 2014). Not surprisingly, the rapid deployment of onshore and offshore wind in the UK between 2010 and 2015 occurred under one of the rare coalition governments composed of the Conservative Party and the Liberal Democrats (see also Ćetković and Buzogány 2016). The market for onshore wind in the UK started developing later compared to leading European wind energy markets. Given the lack of policy commitment and long-term strategy at the national level, onshore wind projects were mainly developed by foreign investors which often faced resistance by local communities (Simmie et al 2014). The weak legitimacy and local acceptance of wind energy technology by local communities were, in turn, used as an argument by political elites to justify the lack of support for onshore wind development. As the UK Prime Minister David Cameron stressed in 2015: 'We will halt the spread of onshore wind farms [….]'. Onshore wind farms often fail to win public support, however, and are unable by themselves to provide the firm capacity that a stable energy system requires (Hackley 2015). Interestingly, the devolution of political power and increasing authority of local and regional governments in energy planning have proven favourable for onshore wind. This is particularly the case for the role of the government in Scotland which has been the most supportive of wind power as part of its economic and industrial policies (IRENA 2012: 128–129). The Scottish Government has adopted a goal of achieving 100 per cent of electricity from renewable energy by 2020 (DECC 2011:9). That Scotland is the engine of onshore wind development in the UK, is illustrated by the fact that in 2014, 'half of all construction activity and over 70 per cent of new consents were in Scotland' (RenewableUK 2015b: 4). The entrepreneurial role of the Scottish Government has been important for providing a protective space for onshore wind but has been less capable of preventing policy changes at the national level. Finally, the absence of credible market formation from the side of the UK government, combined with inadequate provision of skills, knowledge, and finance have constrained the emergence of domestic industrial capacities and local value creation in onshore wind.

Simple CMEs (Denmark, Sweden, Norway, Netherlands)

The policy strategy for promoting wind energy has been most comprehensive in Denmark. The oil crisis hit Denmark particularly hard given that the country was highly dependent on foreign oil and lacked reliable domestic energy resources (in contrast to countries with abundant hydropower such as Sweden and Norway). The options that were considered as alternatives to imported oil were natural gas, nuclear energy and wind power. . Somewhat similar to the German case, in Denmark two technological wind energy subsystems have developed in parallel: 1) small-scale wind turbines promoted by farmers, local communities, and wind energy enthusiasts, and 2) large-scale wind turbine demonstration and production supported by the state (Kamp 2008). In 1976 research programmes for renewable energy were initiated (van der Vleuten and Raven 2006: 3746) and in 1978 the Risø Wind Energy Research and Demonstration Centre was established. The purpose of the latter was to facilitate the development of large-scale wind turbines in collaboration with the Danish industry and energy utilities (Kamp 2008: 284). However, it was the small-scale wind energy sub-system that accelerated the legitimacy and technological development of wind energy in Denmark. Private owners of wind turbines mobilized and established in 1978 the Danish Wind Mill Owners' Association (*Danmarks Vindmølleforening*). In the same year, the Windmill Manufacturers Association was created. The members of the two associations collaborated closely in gradually improving the reliability and effectiveness of wind turbines (Garud and Karnøe 2003). In 1979, the government introduced investment subsidies to individuals and cooperatives for installing wind turbines. This enhanced the development of the domestic wind power market (Buen 2006: 3890). In 1981, the long-term goal of installing 60,000 small wind turbines by 2000 was adopted (Buen 2006: 3890). In 1985 and 1990, the government engaged in long-term planning of wind power projects with large energy utilities. It obliged power companies to install 100 MW of wind power in 1990 and 1995 with a further 200 MW to be installed by 2000. This increased the presence of large power companies in the wind market, although they faced resistance from local communities and were reluctant to undertake wind energy investments that were seen as risky and costly (Buen 2006: 3890). In 1993, Denmark introduced a fixed FiT for renewable energy power producers (IRENA 2012: 56). The onshore wind power installations peaked in 2000 and 2002 followed by several years of stagnation due to the government's decision to liberalize the electricity market and replace FiT with more market-based instruments (IRENA 2012: 57). Interestingly, as noted by Meyer (2007: 353), the government decision to abandon FiT was based on the premature assumption that the European Commission will require harmonization of national renewable energy support schemes along a market-based model. In 2008 the policy environment became more favourable again leading to renewed increase in onshore wind capacity. In 2009, the new support scheme for renewable energies was adopted and in 2011 the government outlined a long-term strategy to become independent from fossil fuels by 2050 with the interim goal of 30 per cent of energy use supplied by renewable sources by 2020. Wind energy was seen as central technology for achieving these goals (IRENA 2012: 58-59). At the end of 2015, Denmark had 3.8 GW of the total installed onshore wind power capacity (EWEA 2016a; EWEA 2016b) (see Table 3). The wind industry (both onshore and offshore) in Denmark employs nearly 29,000 people and contributes to more than 5 per cent of the country's exports (Denmark 2015; see Table 3). In 2014, the Danish wind energy company *Vestas* was a global market leader among wind turbine manufacturers (Statista 2014).

The oil crisis and the referendum decision to phase out nuclear energy in 1980, led to increasing public support for R&D in the wind energy sector in Sweden. However, market creation instruments and long-term targets were lacking. This prevented the uptake of the domestic wind energy market in Sweden (Söderholm et al. 2007: 368). In addition, the R&D support was rather narrow focusing only on large-scale wind power facilities (Jacobsson and Bergek 2004: 221). It was only during the mid-1990s and early 2000s that the installed wind power capacity started to grow due to the introduced investment and production subsidies (Söderholm et al. 2007: 369). The size of the domestic wind energy market was still considerably smaller than in Germany and Denmark (Söderholm et al. 2007: 370) and lacked domestic suppliers of wind energy components (Jacobsson and Bergek 2004: 223). The problem of obtaining building permits for wind parks was evident (Jacobsson and Bergek 2004: 226). In 2003, the government introduced a technology-neutral quota-based green certificate scheme for renewable energy sources which grants one certificate for each MW/h of producer electricity from renewable energy sources (Söderholm et al. 2007: 370). The initial impact of this policy instrument was limited but wind power deployment rates have seen a steady increase in recent years. Several factors contributed to this: the EU renewable energy directive of 2009, the expansion of the green electricity scheme to Norway and cost reduction of wind energy. The more active engagement of the government since 2008 in collaborating with local municipalities and facilitating wind energy project planning has also been an important driver behind more rapid wind energy utilization (Giest 2015). By the end of 2015, Sweden had 6 GW of the total installed wind power (EWEA 2016b), of which 0.2 GW was offshore (EWEA 2016a) (see Table 3). Sweden has thus been able to develop its domestic wind market recently but with the limited involvement of the domestic wind industry and consequently small economic benefits in terms of innovations, job creation, and exports.

Norway has abundant wind potential which could effectively be combined with the existing power system based on hydropower (Blindheim 2013: 339). Similar to Sweden, Norway's efforts in the field of wind energy were mostly confined to basic research and large-scale turbines (Buen 2006). There was a lack of commitment for developing a domestic wind power innovation base and most of the components were imported from Denmark (Buen 2006: 3892). The deregulation and privatization of the power sector and creation of the common Nordic electricity market during the mid-1990s and early 2000s resulted in lower electricity prices and thus little incentive for wind power projects (Buen 2006). In 1999, the government set the target of 3 TWh of wind power production through 2010. To achieve this goal, the state-agency Enova was created in 2002 with the mandate of monitoring and financially supporting renewable energy projects, including wind (Blindheim 2013: 340). In 2003, the first test station for wind power was established in collaboration between the government, scientific institutions, and industry (Buen

2006: 3895). Still, there was a lack of political consensus for promoting onshore wind (Blindheim 2013: 343). The installed capacity of onshore wind increased but at a slower pace than expected. In 2012, Norway joined the green certificate scheme with Sweden as a means of meeting the national renewable targets in a cost-efficient manner (Gullberg and Bang 2015). By the end of 2015, Norway had installed 0.8 MW of wind power, virtually all from onshore wind (EWEA 2016a; EWEA 2016b). The large majority of wind power plants are operated by the state-owned company *Statkraft* or medium and small local energy utilities (Blindheim 2013: 339). The domestic wind market in Norway is thus much smaller than in Sweden, but the lack of domestic wind industry is common to both countries.

The early promotion of wind energy in the Netherlands during the 1970s and 1980s resembled the policy approach taken in Germany and Denmark, characterized by broad R&D support, inclusion of local suppliers, and investment subsidies (Jacobsson and Bergek 2004: 222) (see also Figure 1). The political commitment, however, decreased in the following period and the problems of building permits and spatial planning at the local level hampered market creation (Jacobsson and Bergek 2004: 226). As in the case of Germany and Denmark, both large-scale and small-scale wind energy innovation systems existed in the Netherlands (Kamp 2008: 281). The development of large-scale wind turbines was almost entirely science-led with insufficient collaboration with the industry and electricity companies (Kamp 2008: 281). From the very beginning, the focus of the Dutch wind policy was on energy utilities as main project developers. This was visible in both state-led national wind energy research programmes of 1978 and 1981 (Wolsink 1996). The small-scale innovation system proved more successful but investment subsidies for promoting the demand were introduced only in 1986 (Kamp 2008: 283). Eventually, the progress was slow and ultimately hampered by the problems of local resistance, spatial planning, and the lack of willingness of central authorities to streamline administrative procedures (Jacobsson and Bergek 2004; Kamp 2008). All but one wind turbine manufacturer in the Netherlands disappeared from the market by 2000 (Kamp 2008: 283). In 1994, the budget for wind energy was significantly cut (Wolsink 1996: 1084) and reliance on a market-based approach gained prominence in the light of the privatization and deregulation reform at the end of the 1990s. As a result, a considerable amount of green electricity was imported to the Netherlands instead of being implemented domestically (Agterbosch et al. 2004; van Rooijen and van Wees 2006). In response to this, the government adopted FiTs in 2003 aiming to reduce investment risks and promote the domestic supply of renewable energy (van Rooijen and van Wees 2006: 63). In 2010, the Netherlands had only 3.6 per cent of energy from renewable sources (Statistics Netherlands 2010), compared to the assumed national target of 14 per cent by 2020. Following several changes to the support scheme, in 2011 the government introduced a so-called SDE+ scheme which guarantees a premium market price for different renewable energy technologies but under one budget. The support scheme places an emphasis on competition between different technologies and has the sole purpose of meeting national targets in the most cost-efficient manner. In 2013 a society-wide consensus was reached on the *Energy Agreement for Sustainable Growth* (IEA 2014) but it was acknowledged that national renewable energy targets for 2020 are not achievable (PLB 2014). By 2016, the Netherlands installed 3.4 GW of wind power (EWEA 2016b), of which 0.4 GW was in offshore wind (EWEA 2016a) (see Table 3). The Dutch wind energy sector is not of national significance but it is relatively well positioned in the international market, particularly when it comes to operation and maintenance as well as manufacturing of small wind turbines (IEA WIND 2014: 134).

The discussion so far has shown that all countries, except Denmark, have largely failed to promote innovations in and capture direct economic benefits from onshore wind. The growth of the domestic market was notable initially, followed by a period of stagnation and relatively recent revival, especially in Sweden. How can the analysis of the national political-economic setting account for this development? In terms of the plurality of their political systems, simple CMEs are positioned between compound CMEs and LMEs. They have a multi-party system but with a unitary state structure and a strong tradition of a consensus-seeking policy style. It is precisely this overly consensus-based decision-making process that has hampered wind energy innovations in Sweden, Norway, and the Netherlands. All three countries are characterized by powerful national energy actors in hydropower (Sweden and Norway) and natural gas (Netherlands) with a rather hierarchical structure and strong state involvement, which is particularly true for Sweden and Norway (Petterson et al. 2010). It thus does not come as a surprise that early efforts to promote wind energy were crafted along the existing policy paradigm with energy utilities as natural partners. Such centralized large-scale approaches which relied on energy utilities as drivers of change not only proved inadequate for promoting diverse innovations in the wind energy sector, but were also ill-equipped to ensure market creation due to the reluctance of power utilities to rethink their business models and invest in new and financially risky wind energy. The unitary state structure meant that local governments had no authority over energy policy and thus little incentive to devote resources to issuing permits and adjusting spatial planning plans. The situation in Denmark was the exception due to the lack of conventional domestic energy resources and long tradition of distributed energy generation and cooperatives (van der Vleuten and Raven 2006). This created the space for domestic manufacturers to engage in developing and incrementally expanding the production of wind turbines. It is important to note, however, that Danish energy policy is decided at the national level without a comparable role for federal states and power-sharing between federal governments and the central government, as in compound CMEs like Germany. In addition, the Danish wind industry became increasingly export-oriented and thus less reliant on the domestic market. Finally, Denmark as a small open economy was more strongly influenced by the liberalization pressures from the EU Commission than Germany. These factors made radical subsidy cuts possible and led to several years of stagnation in wind energy deployment in Denmark during the early and mid-2000s. All four countries have strong systems of strategic state–industry–science–society coordination, but only in Denmark could the wind energy industry mobilize the necessary support and build on this base. While Denmark and Germany have benefited from their first-mover position and captured the lion's share of the innovation and industrial potential, the other simple CMEs have only gradually opened their markets to increasingly cost-competitive onshore wind, aiming to enhance energy security and meet international energy and climate commitments. At the same time, some companies from these highly developed and open economies, Netherlands and to some extent Sweden, were successful in entering the global wind energy supply-chain, but far from being on the scale of the Danish wind industry.

3.2 Offshore wind

Compound CME (Germany)

Germany has vast potential in offshore wind in the North Sea and Baltic Sea and its utilization is seen as critical for the country's energy transition (Rohrig et al 2013). As well as the common challenges tied to offshore wind, such as demanding infrastructure and high investment risks, the offshore wind sector in Germany faces additional obstacles. The large areas of shallow waters in the North and Baltic Seas in Germany are environmentally protected areas, which requires building offshore wind parks in deeper waters (20 to 60m) unlike is the case, for instance, in the UK and Denmark (Stegen and Seel 2013: 1485). Another problem is related to a considerable amount of potentially dangerous wartime munition which is still located on the seabed in German territorial waters thus increasing the risks and costs of installing the infrastructure for offshore wind plants (Anzinger and Kostka 2015: 23).

Offshore wind energy was not the focus of decision makers in Germany for a long time. There was insufficient knowledge about the specific challenges and costs of offshore wind technology. The initial FiTs and regulations for connecting renewable energy power plants to the grid were not suitable for driving the expansion of offshore wind projects. In 2002, the government published a strategy for the use of offshore wind in Germany (German Government 2002). It set the objective of 2–3 GW of offshore wind capacity to be installed by 2010, followed by 20–25 GW by 2030. These targets soon proved overly ambitious. Gradually, the regulatory and institutional changes were put forward to streamline administrative procedures, connect important actors in the field, and make offshore wind energy projects more attractive for investors. In 2005, at the initiative of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the German Offshore Wind Energy Foundation (*Die Stiftung OFFSHORE-WINDENERGIE*) was established. It served as the main platform for deliberation on offshore wind energy development among government, industry, and science (Foundation Offshore Wind Energy n.d). It also took the responsibility of overseeing the development of the first large-scale demonstration offshore wind park in Germany 'Alpha Ventus'. In 2006, amendments to the regulatory framework were made to shift the responsibility of providing grid connections from project developers to a Transmission System Operator (TSO) (Fitch-Roy 2015:7). In 2011, the responsible ministry and state-owned development bank (KfW) launched the 'KfW Offshore Wind Energy Programme' with the goal of supporting the financing of offshore wind energy projects (KfW 2015). Following the disputes about the grid connections between project developers and Tennet as the main TSO in 2012, the Federal Minister of Economy played a pivotal role through the so called '*AG Beschleunigung*' (Acceleration) initiative in bringing together the actors from the industry and the government and resolving open questions. This resulted in the revisions to the Renewable Energy Law in 2012 and 2014 which, among other things, further specified remuneration FiT models for offshore wind parks (Anzinger and Kostka 2015: 14–15). The revisions from 2014 also define more realistic long-term targets for offshore wind energy development including 6.5–10 GW by 2020 and 15–25 GW by 2030 (Anzinger and Kostka 2015: 15).

The first commercial offshore wind park in Germany was built only in 2011. However, over the last two years, the German offshore wind market has been the most dynamic in Europe, alongside the UK. In 2015, Germany installed the highest amount of offshore wind power in Europe (2.3 GW) making the total offshore wind power capacity of 3.3 GW (EWEA 2016a) (see Table 3). The expansion of the domestic offshore wind market has provided a considerable boost for the already highly internationally competitive national wind energy clusters located in North-West Germany. German company Siemens clearly dominated the market for offshore wind energy turbines with 62.7 per cent of the EU market share in 2015 (EWEA 2016a). The aforementioned estimates from 2012 show that 18,000 people are directly employed in the offshore wind energy sector in Germany (GTAI 2014: 7) (see Table 3).

The recent success and the relatively certain long-term prospect of offshore wind energy in Germany represent a natural continuation of the German renewable energy market and industrial policy, building on the previously secured legitimacy of wind energy technology, established industrial networks and know-how, and the political consensus on the need for energy transition. The strategic state–market–science coordination proved even more important than in the case of onshore wind, given the large scale, technology uncertainty, and high capital costs of offshore wind energy projects.

Simple LME (UK)

The UK has the most abundant technical potential in offshore wind in Europe (EAA 2009), which in contrast to onshore wind does not compete with agricultural and residential land use.

Early interest and R&D initiatives in offshore wind energy in the UK started in the mid-1990s, but the growth of the offshore wind sector was inhibited by two main factors: 1) liberalization of the electricity market in 1990 which put pressure on energy utilities to reduce costs, and 2) a technology-neutral support scheme for renewable energy sources which provided little incentive for costly and risky infant technology like offshore wind (Smit et al 2007: 6438). The first offshore wind park in the UK was built in 2001 but the rapid deployment of offshore wind only commenced in 2009 with the improvement in the regulatory framework and a more active role of the government (Kern et al. 2014). The RO system was changed to provide more generous support for infant renewable energy technologies. Instead of one certificate per MW/h, offshore wind producers were first granted 1.5 certificates which changed to two certificates for each MW/h in 2010 (Kern et al. 2014: 638). The current support scheme has been fully based on the competition-based CfD since 2015 (Fitch-Roy 2015:7). The Crown Estate is a public body which under the Energy Act of 2004 has the mandate to manage the seabed, grant consents for offshore wind projects, and ensure profit maximization for the state. It also financially encourages implementation of offshore wind farms (The Crown Estate 2016). The role of the Crown Estate has been instrumental in improving the conditions for offshore wind energy investments in UK and facilitating project implementation (Kern et al. 2014). The new support scheme CfD, which separates the budget for offshore wind as non-established technology from more established solar PV and onshore wind continues to provide necessary support for offshore wind projects. However, the government has made the support for offshore wind conditional on clear targets for cost-reduction (The Crown Estate 2012). Consequently, the government has not yet set the targets for offshore wind development after 2020, implying high uncertainty for the sector. Furthermore, in 2015 the government announced plans to privatize the state-owned Green Investment Bank established in 2010 (DBIS 2015). The purpose of the Green Investment Banks was to facilitate investments in non-mature technologies, particularly offshore wind, and privatization is seen by some as a threat to future investments in new renewable energy sectors (Mabey 2015).

Offshore wind is seen as important technology for meeting the UK's national renewable energy targets and promoting economic and industrial development (UK Government 2013). Unlike the locally embedded offshore wind energy sector in Denmark and Germany, offshore wind in the UK has largely been developed in an open-market international fashion under the leadership of foreign companies and research centres (Smit et al. 2007; Wieczorek et al. 2013). Smit et al. (2007) describe the lack of industry-science interaction and access of the UK knowledge institutes to the offshore wind projects on the ground. Since 2009, the government has directed considerable efforts towards promoting innovations, developing manufacturing capacities, and involving domestic companies in the offshore wind supply-chain (Ćetković and Buzogány 2016). However, the majority of components for offshore wind farms in the UK are still produced in neighbouring countries, particularly Germany, Denmark and the Netherlands (RenewableUK/ The Crown Estate 2013; Wieczorek et al. 2013). The estimated number of direct jobs in the offshore wind sector in UK was 6,830 in 2013 (RenewableUK/The Crown Estate 2013: 4) (see Table 3). In terms of the installed capacity in 2015 the UK had 5,098 MW of operational offshore wind power, which represents 45.9 per cent of the entire EU market (EWEA 2016a) (see Table 3).

The success of offshore wind market in the UK can be attributed to several factors including the abundant natural potential and the pressure for meeting national renewable energy targets. However, the key explanatory variable is the closeness or 'fit' between the offshore wind sector and the national political-economic logic. Offshore wind development is associated with the construction of large-scale, concentrated, infrastructural projects. The planning and implementation of such projects resembles in many ways conventional energy projects based on nuclear energy, gas, or coal. Such centralized energy planning is not only familiar to the national government in UK, but it also allows the government to effectively monitor and manage the revenues from offshore wind investments (see also Kern et al. 2014). Unlike the smaller renewable energy projects, such as onshore wind and solar PV, the economic impact of which is most visible at the local level, the revenues from offshore wind farms in the UK are managed by the Crown Estate and transferred directly to the Treasury (Economic and Finance Ministry). In 2015, the Crown Estate generated record net profit, owing partly to offshore wind projects (The Crown Estate 2015). Nonetheless, the still prevailing market-based policy paradigm and the related lack of strategic state–industry–science collaboration have hampered the emergence of a genuine domestic offshore wind industry in the UK and failed to provide long-term certainty for sectoral growth.

Simple CMEs (Denmark, Sweden, Norway, Netherlands)

The first commercial offshore power plant was built in Denmark in 1991. Four years later, the second offshore wind farm was implemented (Bilgili et al. 2011: 907). The development of offshore wind in Denmark was closely tied to the onshore wind industry. Smit et al. (2007: 6436) argue that during this early period only the established Danish wind manufacturers and project developers took responsibility for developing offshore wind technologies and projects. In the subsequent phase, due to the demonstrated feasibility of offshore wind, the offshore wind innovation system expanded to include government agencies, research centres and component and service suppliers (Smit et al. 2007: 6436–37). This led to the first action plan on offshore wind power in Denmark outlined in 1997 in cooperation between responsible ministries and the industry. It suggested the key sites for offshore wind projects and proposed the construction of 4 GW of offshore wind power by 2030 (DEA 2005). The supportive policy instruments and the role of the Danish Energy Authority facilitated the construction of two large-scale offshore wind farms in 2002 and 2003 (Smit et al. 2007: 6437). As noted by Smit et al. (2007: 6441), the government's approach fostered interaction and learning across all important actors in the offshore wind industry. The involvement of citizens and cooperatives was also significant and resulted in the implementation of fully of partly locally-owned offshore wind farms, such as *Middelgrund* built in 2001 (Smit et al. 2007: 6437). The regulatory changes and the transition towards a more competitive market-based support scheme led to pausing offshore wind deployment in the mid-2000s. In the energy strategy through 2050 adopted in 2011, the role of offshore wind is indicated as crucial (Danish Government 2011). Between 2009 and 2013, several new large-scale wind farms were connected to the grid leading to a total of 1.3 GW in 2015. This makes Denmark the third largest offshore wind market, behind the UK and Germany (EWEA 2016a) (see Table 3). Large energy utilities, especially the state-owned Danish company *Dong*, dominate the offshore wind market. The development of offshore wind is supported by considerable domestic investments in R&D, although the greatest share of R&D spending comes from private companies (Megawind 2010) (see Figure 1).

Sweden was the place where the first offshore wind turbine was constructed in 1990 (Bilgili et al. 2011: 207). Since then, several offshore wind farms have been built, mainly as pilot projects for acquiring knowledge and testing the technology (Esteban et al. 2011). The largest offshore wind farm *Lillgrund* with a total capacity of 110 MW was constructed in 2007 by the state-owned power company *Vatenfall* (Bilgili et al. 2011). The policy incentive for constructing commercial offshore wind farms in Sweden has been weak. The existing support scheme for renewable energy sources based on green certificates targets only mature technologies and does not provide an economic rationale for investing in offshore wind (Söderholm and Petersson 2011). The government focus so far has not been on promoting wider utilization of offshore wind and cost-reductions in the technology, but rather on enhancing knowledge accumulation and testing through pilot studies. This should provide a basis for implementing offshore wind once the technology becomes more mature and financially affordable (Söderholm and Petersson 2011: 522). Sweden already has over 50 per cent of energy consumption from renewable energy sources, the highest rate in the EU, due to the high reliance on hydropower and increasing use of biomass and wind energy. The future of nuclear energy in Sweden is questionable and there is a debate whether the country should continue relying on the mature renewable energy technologies 'of the shelf' (e.g. onshore wind and biomass) for meeting energy needs or engage in actively exploring innovation and industrial opportunities in infant technologies (e.g. offshore wind) (Söderholm and Petersson 2011; 4C Offshore 2015). At the end of 2015, the size of the offshore wind market in Sweden was comparatively small amounting to a total of 0.2 GW (EWEA 2016a) (see Table 3).

Norway does not only have large natural potential for exploiting offshore wind, but it also has strong knowledge and industrial base from the offshore oil and gas industry (Normann 2015; Steen and Hansen 2014). The country currently covers virtually the entire power demand from domestic hydropower plants. Offshore wind, however, holds large long-term potential in several areas: enhancing the stability of the power supply, providing low-carbon electricity supply to offshore oil and gas platforms, exporting electricity to the EU market, and upgrading the scientific and industrial base (Tande n.d.). The concrete actions towards utilizing offshore wind in Norway took place in 2005, much later than in neighbouring countries (Normann 2015: 185). There was increasing interest from investors accompanied by public R&D programmes and growing political salience of offshore wind development in the context of regional energy shortages and global climate change and energy debates (Normann 2015). In 2009, the government supported the creation of eight Centres for Environmentally Friendly Energy Research, of which two were specifically dedicated to basic and applied offshore wind research (Normann 2015: 186). This contributed to a sharp increase in wind energy R&D (see Figure 1). In the same year, the Offshore Energy Act was adopted and laid the ground for offshore wind energy strategy and development on the ground (Norwegian Ministry of Petroleum and Energy 2008). The policy efforts, however, remained largely at the level of basic research and demonstration projects without creating the conditions for large-scale testing and commercialization of offshore wind technology solutions (Normann 2015). In light of the declining political support and lack of the domestic market, the established offshore wind industrial clusters composed mainly of companies from the oil and shipping industries shifted the focus towards supplying the growing neighbouring offshore wind markets, mainly the UK and Germany (Normann and Hanson 2015). An interesting case is a largely state-owned Norwegian oil company, *Statoil*, which turned to the Scottish market for implementing offshore wind farms based on the previously developed innovative concept of floating wind turbines (Statoil 2015). By 2015, Norway had as little as 2 MW of the installed offshore wind capacity (EWEA 2016a) (see Table 3).

The debate about and basic research on offshore wind potential have a long tradition in the Netherlands, mainly in the context of diversifying and upgrading the existing offshore oil and gas sectors (Verhees et al. 2015). Cooperation between government agencies, electricity companies, local manufacturers, and research centres was an important part of this process (Verhees et al. 2015). However, within the national wind energy research programmes during the 1980s, little funding was devoted to offshore wind, the focus being on more mature and less costly onshore wind installations (Verhees et al. 2015: 819). The implementation problems in onshore wind projects during the early 1990s renewed the interest in offshore wind. The new Wind Energy Programme in the period 1992–95, for the first time specified a goal of 200 MW of offshore wind capacity by 2010 (Verhees et al. 2015: 819). In fact, the Netherlands was a home to the second commercial offshore wind power plant in the world constructed in 1994 (Bilgili et al. 2011: 907). Two years later, the second offshore wind park was built (Bilgili et al. 2011: 907).

Although a clear legal framework for offshore wind was not in place, the government, based on parliamentary consent and long-term energy planning, granted subsidies for two large offshore wind projects in 2001. They were connected to the grid in 2006 and 2008, respectively (Verhees et al. 2015: 821). In 2002, an ambitious government target of 6000 MW of offshore wind power capacity by 2020 was declared. Nevertheless, progress in developing offshore wind energy policy and a legal framework was slow, not least because of political changes (Verhees et al. 2015: 823). Overall, the potential of offshore wind for innovation and industrial development has been widely recognized, but the government has struggled to strike the right balance between cost-efficiency and active promotion of innovations and market creation in offshore wind. In 2009, a new research programme FLOW (Far and Large Offshore Wind), based on science–industry cooperation, was launched. Its aim is to enhance the scientific and industrial know-how for developing offshore wind energy projects in deeper waters (Verhees et al. 2015: 824). Since 2010, offshore wind has been defined as one of the priority economic sectors (Verhees et al. 2015: 825) and R&D funding for wind energy has almost entirely been directed to offshore wind (IEA WIND 2014:135). The figures from 2015 show that the Netherlands have 426.5 MW in offshore wind power, or 3.9 per cent of the entire EU market (EWEA 2016). The number of direct jobs in the offshore wind industry is higher than the small domestic market would suggest. In 2013, 1900 full-time employed people were registered in the offshore wind sector and this number increased to 2150 in 2014 (Ecofys 2014) (see Table 3).

In sum, all four countries, except for Norway to some extent, have engaged very early in exploring offshore wind energy potential and setting concrete targets relying on the cooperation of government, industry, and science actors. Similar to the situation in the onshore wind sector, a shift in the policy paradigm that would allow for subsidizing the formation of the domestic market for offshore wind has been difficult to achieve. However, where the supportive policy conditions were present, in Denmark and to a lesser extent the Netherlands, the offshore wind sector grew in a way that it was deeply embedded in the network of domestic energy utilities, suppliers, and research centres.

4 Conclusions

This paper has sought to make an inquiry into the political-economic foundations of the technology and policy choices for promoting onshore and offshore wind sectors and innovations across major European economies. We have identified strategic coordination and political plurality as key enabling factors for advancing clean energy technologies focusing on the case studies of onshore and offshore wind. Further, we have proposed a categorization of different national political economies based on the presence or lack of strategic coordination (CMEs vs. LMEs) and the level of plurality (simple vs. compound states). Several important findings and insights have emerged from the analysis.

The analysis of onshore wind development has largely supported the proposed theoretical assumption on political-economic conditions for energy innovations. It has been demonstrated that the rise and growth of the German onshore wind energy sector can largely be attributed to the effective match between strategic state–industry–science–society coordination and the sufficiently plural and decentralized federal political environment. It is in this context that a variety of bottom-up wind energy solutions could thrive and mobilize stable long-term support at different levels of government. Although broadly characterized as simple CME, Denmark proved capable of being a pioneer and one of the leading nations in the wind energy industry. This has mainly come as a result of the inherited tradition of decentralized energy distribution, which distinguishes Denmark from other simple CMEs with similarly strong strategic coordination, but more centralized energy policy community. Some studies even suggest that the

Danish overall economy has evolved into a more decentralized coordinated market economy (Campbell and Pedersen 2007). This further supports the argument about the facilitating role of coordinated but decentral structures for energy innovations. It also suggests that that there are variations in the level of decentralization and plurality among similar forms of capitalism and that the distinction between simple and compound polities should be refined to go beyond the unitary vs. federal categorization. Other simple CMEs (Sweden, Norway, Netherlands) initially supported onshore wind development in a dominantly centralized large-scale manner but the willingness to promote domestic demand ceased quickly due to the resistance from established utilities, liberalization reforms in early 2000's, and the fact that Germany and Denmark as first-movers were faster in capturing the largest economic benefits in the onshore wind industry. The latter emphasizes the importance of economic interests as drivers of energy transition and illustrates the barrier of the centralized consensus-seeking neo-corporatist relations for new energy technologies. All three countries (particularly Sweden) have recently adopted onshore wind on a broader scale, likely as a result of the enhanced state role and international climate and energy commitments. Finally, the case of onshore wind in the UK provides evidence of how unitary market-led political economies tend to be laggards in providing stable support for new more decentralized energy technologies. Interestingly, and in support of the general argument, the political devolution in UK and the entrepreneurial role of the Scottish Government have facilitated onshore wind deployment, which draws attention to the dynamic character and institutional changes of national political economies.

The study has revealed important similarities but also some differences between onshore and offshore wind development. Although the offshore wind sector does not represent simple diversification from onshore wind (Jacobsson and Karltorp 2013), the countries with the strong onshore wind industry and secured legitimization of wind technology (Germany and Denmark) have also been among the leaders in the domestic offshore market and industrial competitiveness. Somewhat surprisingly, the UK has emerged in recent years as the most dynamic offshore wind market. This can be explained by the large-scale top-down character of offshore wind coupled with vast natural resources, industrial objectives, and the pressure for meeting national renewable energy targets. However, the long-term prospects for the offshore wind market, due to policy changes, have proved less stable lately than in Germany and Denmark. Furthermore, due to strategic coordination, CME countries (Germany, Denmark and even the Netherlands) have generated more locally embedded offshore wind sectors with a stronger presence of local companies and research institutes, than is the case in the UK (see Wieczorek et al. 2013). Another interesting finding is the increasing focus on promoting offshore wind market and innovations in the countries that were laggards in onshore wind (the UK but also the Netherlands and Norway). This shows the attempts of these countries to capture market share in the emerging offshore wind sector and it further underlines the critical role of industrial and economic motives behind clean energy policies. As pointed out by Pegels and Lütkenhorst (2014: 532) in their study of wind and solar PV in Germany: 'In Germany, any transformative alliance can only succeed if it builds on a platform of employment, competitiveness and innovation...'. The experience from onshore wind in Europe has shown that it is not energy utilities, but the manufacturing industry and private and local customers that are drivers of innovations and market development. This is somewhat different in the offshore wind sector, due to high capital costs and the large-scale nature of offshore wind projects (Jacobsson and Karltorp 2013).

The revealed relationship between national political-economic structures, industrial interests, and wind energy innovations provide important answers to the question as to why countries exhibit different enthusiasm and success when it comes to clean energy transitions. The study has also shown that national political economies are dynamic and evolving entities and that there are multiple factors at different governance levels that shape national responses to renewable energy development. At the same time, cross-national linkages as well as cross-sectoral dynamics also play an important role, pointing towards the limits of analysing these developments in a solely national or sectoral context. Although the proposed framework can be useful for analysing other renewable energy technologies, the findings from this study cannot be generalized given the specific character of the wind industry. More research is needed to adjust the proposed conceptual framework to account for the model of capitalism in developing and emerging economies and how it impacts renewable energy diffusion in these countries.

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