

COMPARING NUCLEAR POWER TRAJECTORIES IN GERMANY AND THE UK:

from ‘regimes’ to ‘democracies’ in sociotechnical transitions and discontinuities

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EXTENDED ABSTRACT

This paper focuses on what is arguably the single most striking contrast in contemporary major energy politics in Europe (and even the developed world as a whole): the starkly differing nuclear policies of Germany and the UK. Germany is seeking entirely to discontinue nuclear power, phasing the technology out by 2022. The UK professes the aim of a ‘nuclear renaissance’ and plans to promote the most ambitious new nuclear construction programme in Western Europe. With nuclear power continuing to assume such iconic cultural and political salience worldwide – and constituting such a significant part of these and other countries institutional and energy mixes – the stakes are high.

This paper is based around a simple yet quite fundamental question: what are the drivers that produce such divergence in these energy developments between these two countries? Answers to this question may assist in wider understandings and conceptualisations of sociotechnical discontinuity. And they may be especially salient because – as we shall show – more fine-grain appreciation of conditions in these two countries actually compound (rather than relax) the evident discrepancy. The present study seeks to address this by developing and applying nine criteria constituted by 30 parameters, designed on the basis of various literatures to explore key relevant factors bearing on nuclear incumbency in these two countries.

The nine criteria are: 1) general market conditions in the two countries in respect of different kinds of capital investment in electricity supply; 2) the comparative degrees of penetration (and thus – to this extent – associated influence) of nuclear power in the electricity generating mix; 3) the relative strengths of national nuclear engineering sectors in terms of performance in manufacturing and operational equipment supply and associated industrial lobbies; 4) the relative magnitudes and costs of the available national renewable resource potentials; 5) the scale of established national industrial capacities and interests around technological alternatives to nuclear power as a low carbon energy option (including solar, wind, offshore technologies); 6) the relative scales of military-related nuclear activities and interests; 7) relevant characteristics of relevant national political institutions and elite policy cultures and procedures; 8) public opinion and the broader presence and activity levels on the part of relevant anti-nuclear social movements; and 9) contrasts in variously-construed ideas of the respective overall ‘qualities of democracy’ in the two countries.

Despite the complexities, this analysis finds a relatively clear picture with respect to the first five criteria. These involve dynamics internal to the ‘focal regime configuration’ of nuclear power and its associated (nested and overarching) ‘sociotechnical systems’, ‘niches’ and ‘challenger technologies’. On this basis, it might be expected that Germany would be significantly *less* likely than the UK to discontinue nuclear power. Indeed, these five criteria together might in this case be taken quite confidently to predict the opposite of the observed pattern. Yet these criteria address the key basic ‘internal’ factors that tend to be emphasised in conventional analyses of dynamics in sociotechnical regimes and sectoral patterns of innovation. In short, in these ‘conventional’ terms, the UK’s renewed enthusiasm for nuclear in comparison to Germany’s nuclear phase-out seems rather hard to explain.

It is under the remaining four criteria – relatively remote from the focal regime configuration around nuclear power – that seem to align more with the observed pattern of developments in the two countries. Particularly important here, are the strongly differing military nuclear strategies and the contrasting qualities of democracy in the two countries – which are alone in very clearly favouring the observed pattern of discontinuation in Germany rather than the UK. Manifesting correlation rather than causality, this does not definitively explain the contrast. But the fact is, that it seems in this important case of sociotechnical discontinuity, that the criteria representing the most potentially relevant drivers concern dynamics that are quite remote the focal regime configuration.

Of course, nuclear power (like all large infrastructures) displays many distinctive features. There are many ways in which this examination (like any analytical framework) might miss significant factors. But the fact that a pattern so challenging to theory should apply in such an important case, does raise important questions for conventional analysis of sectoral innovation and sociotechnical regimes in general. Crucial here is that the dynamics of the focal regime configurations do not seem merely to be of secondary importance, but are actually quite clearly aligned towards an entirely *opposite* outcome. So the observed pattern of events in this case, apparently suggest that broader political factors typically marginal to existing theory, actually *dominate* and *reverse* what would otherwise conventionally be expected to be the opposite picture.

In this respect, the present analysis reinforces some wider emerging literatures in this field. There seems considerable scope fruitfully to move attention away from such exclusive concern with relatively narrow dynamics specific to a focal regime configuration - involving specific (but variously-construed) categories like 'regimes', 'landscapes' 'niches', 'incumbents' and 'challengers'. What seems to come more to the fore in this case, are more general and pervasive qualities in wider political structures, discourses and processes. Seemingly especially important, is a rich body of recent discussion concerning diverse qualities of democracy – which (despite many differences of detail and framing) is unanimous in characterising Germany more positively than the UK. Given associated levels of secrecy, it is relatively difficult to ascertain the importance of the additional stark contrast in nuclear military strategies in Germany and the UK. But in the event this were a significant driver, the fact that military nuclear commitments remain virtually unmentioned in British policy documentation concerning rationales for supporting nuclear power, would anyhow compound the inherent implications of the secrecy itself, in further underscoring the importance of contrasting levels of democratic accountability.

Whatever the precise drivers, then, it seems quite compelling in at least this specific case, that this particular – especially prominent – sociotechnical discontinuity is rather poorly explained by reference to the circumscribed concepts highlighted in conventional narrow versions of transitions theory. What is evidently more important here, are wider political factors relating broadly to general 'qualities of democracy'. Perhaps then, democracy is itself – in all its diverse, multidimensional and contested forms – a relatively neglected factor in the achieving of transformative sociotechnical change? Of course, this raises many counter-questions, precluding any unequivocal conclusion even in this case. But there do at least seem important implications for further research.

CONCEPTUAL AND EMPIRICAL BACKGROUND

Introduction

This paper is based around a simple yet under-explored query in relation to research on Sustainability Transitions (ST) and socio-technical change: why are radically different pathways to sustainability undertaken by different countries that are fairly similar in terms of their profiles regarding development, wealth, size and existing portfolio of energy provision? The paper explores this question by examining perhaps the most starkly differing examples of sustainable energy policies in the ‘developed’ world: Germany and the UK. Germany has committed to a shift towards a decentralised low carbon energy system through phasing out nuclear power by 2022 following the Fukushima nuclear disaster in 2011 (World Nuclear Association, 2014) (BBC News, 2011) whilst the UK has plans for a low carbon energy transition in which the most ambitious nuclear new build programme in Europe is an integral part (DECC, 2011). Both the energy policies of Germany and the UK have radical emissions reductions as a key justificatory aspect of their transition. The difference in motivations generating these general approaches cannot therefore simply be explained in terms of differing intensities in policy interests in transitioning to a low carbon economy. Rather, these two countries highlight the diverse, contested and dynamic nature of pathways to sustainability (Leach, Scoones, & Stirling, 2010). They suggest that other factors related to wider socio-technical contexts may be motivating these divergent approaches.

The Richness and Diversity of ‘Regime Theory’

In assessing the differences between the cases of Germany and the UK this paper builds on burgeoning work related to ‘sustainability transitions’ (Markard, Raven, & Truffer, 2012) and what might broadly be understood as socio-technical regime theory (F.W. Geels, 2004). Central to such approaches is the idea that technological change entails co-evolutionary interactions between technological artefacts, institutions, and agents. Over time, new and innovative ‘niche’ technologies diffuse, transform and stabilise at the ‘regime level’ (Kemp, Schot, & Hoogma, 1998) In so doing, new regimes arise, with differing sets of artefacts, rules and regulations becoming apparent (Smith, 2007).

The idea of a technological regime was developed by Nelson & Winter (1982), conceptualising the dominant engineering factors that guide technologies along particular ‘trajectories’. These ideas were later further developed by Dosi (1982), whose work on technological paradigms explored how impacts on contrasting directions of innovation and associated patterns of continuous and discontinuous change are shaped by the interplay between scientific advances, institutional variables, economics and technology. Focusing strongly on sustainability challenges, recent studies of technological trajectories have been further developed to build more detailed understandings of how markets, socio-technical, scientific, and cognitive aspects interact in technological change (F. Geels & Schot, 2004; Kemp et al., 1998). As part of this broader body of study, the Multi-Level Perspective (MLP) has been an especially dominant approach (Frank W. Geels, Hekkert, & Jacobsson, 2008; Frank W. Geels, 2002, 2006; Jørgensen, 2012; Markard & Truffer, 2008) Beginning with a particular instrumental focus on policy strategies for ‘Strategic-Niche Management’ (SNM), ‘niche’ technologies have been identified as a focal point of entry – often understood as the key driver behind socio-technical transitions (Berkhout, Smith, & Stirling, 2004; Kemp et al., 1998; Schot & Geels, 2008; Witkamp, mRaven, & Royakkers, 2011). Successful niche technologies may acquire momentum and eventually grow to such a scale that they constitute ‘challenger innovations’ (Strunz, 2014) contesting the dominant position of whatever in this context is held to be the ‘incumbent’ sociotechnical regime (Grin, Rotmans, & Schot, 2010).

Socio-technical change is seen as usually occurring incrementally over a period of decades, as ‘niche’ technologies struggle to develop because they do not ‘fit’ with the dominant technological regimes already established (F Berkhout et al., 2004). Due to a range of factors including economics, guiding principles, industrial structures, user relations and markets, policy and regulations, regimes are conceptualised as semi-coherent and stabilising sets of rules, regulations and technologies that make it challenging for new ‘niche’ entrants to emerge, as they do not conform to, or are even seen as potentially destabilising threats by incumbent actors within dominant technological regimes (Nill & Kemp, 2009). However, it has been noted for some time, that there has perhaps been too much attention on ‘niches’ as the central drivers of socio-technical transitions (Raven, 2005; A. Smith, Stirling, & Berkhout, 2005), and not enough focus on ‘interactions’ between niches and regimes for example (Witkamp et al., 2011), where further explorations of processes of ‘lock in’ (Unruh, 2000), ‘path-dependency’ (Arthur, 1994; Pierson, 2000), ‘endogenous renewal’ (F Berkhout et al., 2004; Frank W Geels & Schot, 2007), ‘entrapment’ (Walker, 2000) and ‘obduracy’ (Hommels, 2005) are required to understand the regime level.

Two ‘real world’ factors have motivated attention towards questioning how dominant regimes maintain stability against ‘challenges’ from the niche level. One arises in various problems associated with the practical application of the ‘transition management’ (TM) approach in the Netherlands, where sustainable technological niches did not develop in the widely-desired way, but faced significant challenges from incumbent actors ‘capturing’ and ‘resisting’ change. Here, politics of various kinds appeared to dominate the process (Hendriks & Grin, 2007; Kemp, Rotmans, & Loorbach, 2007; Kern & Smith, 2008; Verbong & Geels, 2007). In addition to resistance by incumbent actors in unsustainable regimes, increasing urgency surrounding climate change (and perceived policy failures in other responses), is argued further to have reinforced a dissatisfaction with incremental socio-technical transitions, prompting instead attention to more ‘radical’ transitions enacted over shorter time frames (Markard et al., 2012; Nill & Kemp, 2009; A. Smith, Voß, & Grin, 2010). Incremental development of niches is increasingly thought of as an unreliable way to bring about the necessary rapid change, without corresponding efforts targeted directly at ‘undoing’ and ‘destabilising’ the incumbent regimes themselves (F. W. Geels, 2014; Turnheim & Geels, 2012). So, recent work has highlighted the importance of dedicated governance interventions not only to support growing niches and challenger technologies, but also deliberately to discontinue (Bergek, Berggren, Magnusson, & Hobday, 2013; Stegmaier & Kuhlmann, 2013) incumbent unsustainable technological trajectories (F. W. Geels, 2014).

This paper takes this rich body of ‘regime theory’ as a starting point from which to seek to build a specific understanding of why discontinuation of nuclear power is taking place in Germany, whilst continuation and renewed nuclear enthusiasm are evident in the UK following Fukushima. This departs in some ways from much earlier comparative analysis of the respective energy systems of the UK and Germany. Given their purpose, many earlier studies justifiably take renewables policy as the primary focus of analysis, with contrasting German and British nuclear decisions being mentioned as an exogenous factor in building longitudinal understanding of renewable energy policy developments. Such studies are generally not concerned with close inspection of the regime dynamics around the nuclear industries of the UK and Germany in their own right (Bailey, 2007; Kleiner, 2008; Klessmann, Nabe, & Burges, 2008; Lipp, 2007; Lockwood, 2014; Lovinfosse, 2008; Mitchell, Bauknecht, & Connor, 2006). Yet in previous literatures, nuclear technology has been highlighted as a paradigmatic example of processes driving regime stability – such as ‘autonomy’ (Winner 1979), ‘lock in’ (Cowan, 1990) and ‘entrapment’ (Walker, 2000). And, taking account of this, other literature has recognised the role played by nuclear power as a dominant force in shaping wider energy regimes (Elliott, 2006). But again, the particular dynamics that mediate such effects in the UK and Germany have only rarely been a focus of comparative attention.

The Present 'Inductive' Approach

This paper seeks to help remedy this relative lack of recent attention to the key elements that constitute nuclear regimes. Based on central insights in regime theory and other bodies of thinking bearing on large scale sociotechnical change, the paper develops a broad range of nine criteria constituted by 30 parameters in order to assess relatively inductively the contrasting patterns of change in Germany and the UK. Including technical, economic, social, and political aspects, these address variously-construed salient attributes both of incumbent nuclear regimes and what has been characterised as 'challenger' technologies (Ansari & Krop, 2012) – in this case decentralised renewables. This explicit and systematic framework is intended to encompass a broad diversity of perspectives on regime dynamics in sustainability transitions, as well as wider theories of directionality in technological trajectories more generally, and studies focussed on contrasting implications of attributed economic, technical, and political features of nuclear power itself (Hultman, 2011; Jewell, 2011; Linares & Conchado, 2013; MacKerron, 2004; Sovacool & Valentine, 2012; Verbruggen, Laes, & Lemmens, 2014).

With respect specifically to each criterion in turn, provisional observations are made on a *ceteris paribus* basis concerning the most likely hypothetical respective 'directions of travel' of the 'nuclear regime' in Germany and the UK with respect to the picture yielded under that criterion. Here, a distinction is helpful between criteria that relate most strongly to dynamics that are 'internal' to this 'focal regime configuration' around nuclear power (and its associated constituting and directly challenging structures), and those that implicate wider and more pervasive 'external' social and political factors. 'Internal' factors thus include those processes most strongly explored by conventional regime theory, concerning relations within variously-definable 'regimes' within or encompassing nuclear power itself and its supply chains (including the wider electricity generating industry). Factors internal to this conventional focus of attention also include more agonistic relations directly and immediately mediated by sectoral market, industrial and policy processes, with emergent niches and potential 'challenger regimes' around renewable and other candidate strategies for sustainable electricity production.

These 'internal dynamics' contrast with factors understood to be 'external' to this focal regime configuration, like general political culture, elite policy discourse, patterns of public opinion and wider attributes of democratic governance. Some of these factors are not specific to the particular context of the nuclear power regime within its sectoral setting in electricity supply, but are instead more generally pervasive through each political environment taken as a whole. In one sense, they might be held to relate to factors characterised as 'the landscape' in conventional regime theory (Baker, Newell, & Phillips, 2014). But they are not just about 'high level', 'long run' processes overarching regime developments (Hess & Mai, 2014). They are broader in scope, but also include many fine-grain details of social and political culture that deeply pervade the constituting equally of regimes and niches. In this sense, some of what are referred to here as 'external' factors are increasingly well addressed in the recent 'political turn' in sustainability transitions studies [ref]. This involves attention extending away from narrower policy aspects alone, to also encompass wider political dimensions of regime dynamics and the actions of incumbents and new entrants (Baker, Newell, & Phillips, 2014; F. W. Geels, 2014; Hess, 2014; Meadowcroft, 2009; Smink, Hekkert, & Negro, 2013; Stirling, 2014).

But, in crucial respects, the scope of the present attention to 'external' political implications goes beyond much of this discussion. It highlights the potential relevance of very general and pervasive constituting features of political environments, that are not necessarily best viewed hierarchically as overarching levels, but perhaps rather in more horizontal ways, as fabrics that constitute even the most specific loci in implicated regimes or niches. An example here concerns multidimensional consideration of the general qualities of democracy in each respective national setting (criterion nine). And 'external' criteria also include quite specific factors that are beyond the immediate environment of the focal regime configuration around nuclear power, but which are nonetheless perhaps best understood as parallel characteristics in other sociotechnical regimes rather overarching 'higher level' environments. An example here concerns military dispositions in

each national case – and depth of strategic commitment to capabilities for delivering weapons of mass destruction (criterion seven).

Although not central to conventional ‘regime theory’ in its present forms, the potential relevance of including attention to these ‘external’ factors in this case, is highlighted more in older literatures on the political and industrial circumstances of nuclear power. Anteceding the development of contemporary regime theories, this work goes back to Ellul, Oppenheimer, Russell and Eisenhower’s ‘military industrial complex’ in the 1950’s (Camilleri, 1984). Here can be found intense discussion bearing on the particular relevance of and for nuclear technologies, of general considerations of democracy. For Lovins (1977) nuclear represented a “hard”, centralised energy path which in part due to proliferation potential had profound effects on the very fabric of society in terms of authoritarian forms of governance. Bookchin (1996) argued that the extension of democracy through decentralisation of power was prevented by the continuation of nuclear.

Such themes were also highlighted by Patterson (1977) who in a description of the ‘fissile society’ outlines the ways that the specialist knowledge and historical military emergence creates an under-scrutinised technical elite to which politicians ‘bow’ to without proper deliberation on differing technological trajectories that do not include nuclear, later addressing the secretive nature of the ‘plutonium business’ (Patterson, 1984). Langdon Winner also used nuclear to interrogate the ‘politics of artefacts’ argues that there is a risk of the ‘mentalities’ and ‘social structures’ associated with nuclear ‘spilling over’ into society as a whole, with negative effects on democracy (Winner, 1980). Indeed, discussions of ‘democratic deficits’ within nuclear decision-making was previously a major theme of academic enquiry in many disciplines (Blowers & Pepper, 1987; Massey, 1988; Schrader-Frechette, 1980; B Wynne, 1982). This comes together with issues around the nuclear power industry itself, the huge military implications of national nuclear technological capabilities both in the production of fission and fusion weapons and propulsion for high performance submarine platforms for their effective strategic delivery. These links have long been strongly disavowed – even ridiculed – in much industry documentation and associated policy analysis. A unique international regulatory regime has been developed in order to assure effective separation. But – irrespective of the answers – the resulting persistent questions raised by critics concerning secrecy and covert drivers in policy making, do also bring together issues of the military salience of nuclear power with issues around the qualities of democracy.

In order to address this issue of general contextual ‘qualities of democracy’, the ‘external’ criteria developed for this paper will focus on a recently-emerging dedicated literature on exactly this theme (Bühlmann, Merkel, & Müller, 2011; Economist Intelligence Unit, 2010; Hess & Mai, 2014; A Lijphart, 2012; Munck, 2014). Although well addressed in the earlier literatures sketched above, these issues are relatively neglected in conventional regime theory. Indeed, some emerging concerns coming out of the Dutch transitions experience have involved recognitions that the TM approach reveals potential democratic tensions over who decides the course a particular transitions pathway takes, and the means through which such decisions are reached (Hendriks & Grin, 2007; Hendriks, 2009; Shove & Walker, 2007). In putting forward a countervailing case for the democratic potential of TM, Jhagroe & Loorbach (2014) confirm a gap in the literature focussed on democratic issues in the field of sustainable transitions. And outside the ‘transitions management’ field, recent important work by Hess & Mai (2014), uses data on democratic ratings of countries from the Economist Intelligence to draw attention to the overlooked factor of democracy in determining differing directions in sustainable energy policy in South East Asia. So the present focus on ‘qualities of democracy’ as ‘external factors’ not only chimes and builds on this recent work, but offers a way systematically to test in a particular case, some of the key implications.

Some Conceptual Issues

In addressing these complex issues, some care is necessary at the outset to avoid an impression of insufficiently nuanced or discriminating usage of terminology – for instance around concepts like ‘regime’ or ‘democracy’. On the latter, it should be especially emphasised, that it is not the purpose of this paper to seek to draw conclusions concerning the relative ‘levels’, circumstances or overall status of ‘democracy’ in Germany and the UK (whatever this may mean). Indeed, the paper will conclude by stressing the need for more dynamic interpretations of democracy as processual and relational (rather than categorical) and as situated and scale-independent (rather than synoptically-structured and context-free) (Stirling, 2014).

A similar point might also usefully be made with respect to other concepts used above in setting the scene for this study – like those developed in what is termed sociotechnical ‘regime theory’ (Rip and Kemp, 1998; Geels, 2002; Smith & Raven 2012]. Here, the most important point distinguishing this study from much of the literature surveyed above, is that it seeks to avoid simply reproducing the form of elaborate prior – deductive-style – theoretical frameworks (like those concerning the ostensibly individually discrete and collectively complete ‘levels’ of regime theory). Regime theory has been used as a deep and rich basis of thought from which to formulate criteria for inductive hypothesis testing of contending candidates as drivers of sociotechnical discontinuity. But the findings that this will yield will very deliberately in this study, not be explicitly framed in advance in terms of the well-established categories like ‘niches’, ‘regimes’, ‘landscapes’, ‘phases’, ‘incumbents’ or ‘challengers’. Instead, this study will focus around the less fine-grain concept of ‘focal regime configuration’. This addresses what is for our purposes, the most important locus for salient dynamics and relations operating between this constellation of analytical categories. But it does this in a fashion that acknowledges that the resulting picture is structured by ‘polar’ co-ordinates around the subjective focus of the observer, rather than implying an objectively complete ‘Cartesian’ framework of ubiquitous ‘levels’ or assuming that the boundaries and mechanics of implicated entities and drivers have been precisely determined.

The reason for this, is the under-determined and multidimensional nature of the associated social dynamics in this field. This arguably in any case means concepts of ‘niches’, ‘regimes’, ‘landscapes’, ‘phases’, ‘incumbents’ or ‘challengers’ (like associated broader social theoretic categories: actors, structures, relations and processes) are better addressed not with a “monothetic glance”, but each as a “polythetic flux” (Ritzer, 2000). That is, all these categories themselves and their idealised relations (not just the instances) are not necessarily definable in the kinds of clear-cut ways suggested in their assertive usage (Schutz, 1967)(Borgatta & Montgomery, 2000). In other words, it is often far more ambiguous than is typically conceded which instances of real-world phenomena relate to which particular analytical categories (like ‘levels’ or ‘phases’) and what the implications might be. For instance, what exactly is a ‘regime’ in this context (Shove, 2012): a particular nuclear design complex (Cowan, 1990); nuclear power as a whole (Frans Berkhout, 1997); the national electricity generating system in which these are embedded (Strunz, 2014); wider international infrastructures and supply chains associated with electricity supply in general (Malerba, 2002) or the entire technological and institutional environment of energy provision within which in seamlessly entangled (Hughes, 1989). With what counts as any one regime thus recognised polythetically to be radically ambiguous, how to conceive using an ontology of three nested ‘levels’, the dynamics within this incommensurable constellation of candidate regimes – and between these and parallel constellations?

This is important, because there is in this field as elsewhere in social science, a typically much stronger reflexive relationship than is declared, between representations of the supposedly objective phenomena under scrutiny and the subjective circumstances of analysis (Žižek, 2006). Assertion of analytical schemes using these kinds of category may often be much less precise than they purport – saying more about the disciplinary and policy imperatives bearing on the system of research, than the phenomenological dynamics of the systems

under research. As a result, all such formally codified category schemes may offer a good basis for building a research community, at the same time as seriously under-characterising the totality of salient relations in the real world with respect to which that community is ostensibly defined. Pressures for policy justification, discipline-creation and identity-forming can foster more serious vulnerabilities than are admitted, to unduly reductive simplification and hubris – and associated uncertainty, ambiguity, indeterminacy and surprise. The fact that a reified single notional ‘birds eye’ view of ‘the regime’ is very useful for the purpose of justifying intended high level policy making, is not of itself necessarily sufficient to warrant its acceptance as a satisfactory framework for describing the phenomena themselves, especially in the ‘toad eye’ view of typical real-world practice (Giyawali, 2010).

Of course, as a general issue in academic enquiry, this point would bear as strongly on the current analytical framework as those to which it owes a debt. It is for this reason that the present study attempts a more inductive approach, with respect to a range of specifically-defined criteria grounded in other literatures, rather than an elaborate array of finely disaggregated but under-defined categories and mechanisms. It is also for this reason, that the empirical argument forming the main part of the paper, is substantiated wherever possible by reference to independently verifiable statistics, rather than just the narrative interpretations of the authors. The categories used in defining these parameters are independent from those used to develop resulting understandings. So the evidence deployed here remains socially-constructed and contestable. But the absence of such a circular relationship between constituting assumptions and concluding interpretations at least offers some measure of accountability for the argument as a whole.

Perhaps the main exception to this, is with regard to the concept of democracy introduced in the last section. As observed above, the analytically problematic nature of this term combines with its normative loading to present particular difficulties. These will be returned to in light of the empirical discussion at the end of this paper. But for the moment, the use of the concept itself can be justified in the same inductive terms advocated here – as a heuristic for addressing a relational process, rather than a fixed framework for addressing a static category. In other work in this vein, Stirling has characterised such an appreciation of democracy as a continual open-ended process of struggle by the least powerful to the capabilities for challenging power (Andrew Stirling, 2014) Drawing on a wide literature (Bourdieu, 1998; Gramsci, 1971; Luhmann, 1995; Lukes, 2005; Sen, 2000; Simon, 1991; VeneKlasen & Miller, 2002), this addresses ‘power’ in all its diverse and multidimensional forms as ‘asymmetrically structured agency’ (Stirling, 2014). This in turn allows a more inductive, context-specific and relational understanding of what ‘qualities of democracy’ might mean in any given setting. And this characterising of democracy in terms of multiple polythetic relational qualities, rather than single notionally unambiguous category helps avoid the dangers criticised above in relation to key concepts in conventional regime theory. In setting the scene for this study, it can at least be argued that the concepts employed in the framing of this enquiry do not of themselves strongly deductively structure the forms that can be taken by the results. Further elaboration of exactly what the implications may be, is best left until the findings have been presented.

Case Study Background: Nuclear Power in the UK and Germany

Civilian nuclear power finds itself at a pivotal juncture. The technology could provide a source of low carbon energy and has been compared in various life cycle analyses to wind and solar power in terms of the amount of carbon emitted during mining, construction, and electricity production (Fthenakis & Kim, 2007; IPCC, 2012; Lenzen, 2008; Sims, Rogner, & Gregory, 2003). Although there are critical assessments of such conclusions (Sovacool, 2008), what remains undisputed is the emissions produced through the life-cycle of nuclear power

are substantially lower than those produced from comparable fossil-fuel 'base-load' technologies such as large coal-fired power plants and gas-fired power stations (Kleiner, 2008).

However, predictions of an impending 'nuclear renaissance' (Nuttall, 2004) routinely espoused by industry (Nuclear Industry Association, 2013) and governmental policy (DECC, 2013) remain far from certain. Scepticism regarding the apparent imminent nuclear renaissance is justifiable not only due to the various governmental phase-outs and cancellations occurring after the accident at the Fukushima Daiichi nuclear power plant in March 2011 (Ramana, 2013), but also by rigorous analysis that simply points out the gap between the rhetoric of nuclear advocacy compared with the actualities of new build programmes – a result of various economic and political impediments, not to mention the presence of concrete policy alternatives which further complicate any notion that a 'renaissance' is inevitable (Bradford, 2012; Schneider & Froggatt, 2014; Thomas, 2012).

Nuclear policy continues to be infused with a plethora of political challenges, controversies, and uncertainties. These include unresolved issues surrounding waste disposal, on-going risks related to proliferation of nuclear weapons, recent accidents, 'negative learning experiences' in terms of increasing costs over time, long lead times for construction, public concern and protest, to name a few (Hultman, 2011). For these reasons nuclear remains one of the most "iconoclastically controversial" of modern technologies (Wynne, 2010: 1). The multitude of issues highlights the important point that nuclear remains a 'political choice' rather than a 'scientific necessity' - the latter being a status often afforded to nuclear by certain contemporary analysis (see Lynas, 2013).

This recognition of nuclear as a 'political choice', relates precisely to the case study focus of this paper. Arguably the comparison between the respective responses of Germany and the UK in response to the Fukushima accident in Japan in March 2011 illuminates most clearly the political dimension of nuclear policy and sustainable transitions more generally. Germany with its pre-Fukushima nuclear portfolio of 17 reactors producing a quarter of electricity, made the decision to phase-out nuclear completely by 2022, with the immediate closure of 8 reactors (World Nuclear Association, 2013). The UK with its nuclear portfolio comprised of 16 reactors producing 18% of total electricity, reaffirmed its pre-Fukushima commitment to construct around 16GW of new nuclear power by 2030, with potential for a total of 19GW after that (ibid).

Much has been written regarding the range of potential implications and challenges concerning the German *Energiewende* (Bruninx, Madzharov, Delarue, & D'haeseleer, 2013; Griffin, Buisson, Criqui, & Mima, 2013; Huenteler, Schmidt, & Kanie, 2012; Smith Stegen & Seel, 2013). Similarly, the UK's nuclear policy has been scrutinized mainly in terms of the potential difficulties that aiming to construct 16GW of nuclear power in a liberalised energy market presents (Harris, Heptonstall, Gross, & Handley, 2013; Linares & Conchado, 2013).

What has not been focussed on to the same extent, is an inspection of the factors that influence the differing direction of travel of the respective socio-technical regimes of the UK and Germany with respect to nuclear power. This is the area this paper contributes towards. This paper speaks to literature that is focussed on understanding the dynamics of 'innovation journeys' (F.W. Geels & Verhees, 2011; Frank W. Geels et al., 2008; Schot & Geels, 2008; Verbong, Geels, & Raven, 2008), and why certain technological trajectories evolve in the way they do. The comparison between the UK and Germany is also of importance in terms of understanding energy policy more generally. As Ramana (2013:73) observes, "The Fukushima crisis, unfortunate as it is, offers a rare opportunity to observe the shifts in nuclear policies of multiple countries in response to a common event". It is also identified that this remains an understudied line of enquiry. Researchers have shown great interest in why some countries choose to pursue nuclear weapons or not, however not much work has been done on civilian nuclear power, the literature remaining 'sparse' (ibid: 73). This paper contributes directly to this gap in the literature.

Jewell (2011) focusses on the pressures acting in the 'developing world', with some previously non-nuclear countries also deciding to pursue nuclear strategies based around a study of attributes of countries originally adopting nuclear power, and the capacities that are required for such a path to be feasible. This outlines wealth, large economy, political stability, 'effective' government, large electricity grid, security of fuel supply, and international grid connections as being determinate in whether countries are likely to have the capacity to adopt. This analysis however, focuses on decision-making prior to any nuclear programme being present in the country rather than an understanding of what policies have recently emerged in countries with long established nuclear programmes, and does not focus in more detail on aspects of politics, governance and technological alternatives. Sovacool and Valentine (2012) focus on a varied set of socio-technical dimensions which contribute to the evolution and maintenance of nuclear power programmes. They identify (amongst other things), 'centralised' governance structures as being a necessary factor for a large nuclear power programme. More specifically related to the case studies under consideration in this paper, the divergent European responses to Fukushima and the political factors giving rise to Germany's closure have been studied (Jahn & Korolczuk, 2012; Winter, 2013; Wittneben, 2012).

However, these papers tend to look at the political conditions relating to the short time span following Fukushima such as the local elections which were a main influence on the decision-making of the Merkel Government, or aspects such as protest movements, and whilst such conditions are clearly important to an analysis of the policy responses to Fukushima, this paper seeks to cover a broader range and time frame than done so by work so far. However the present paper seeks to explore the wider and more long-term dynamics that enabled such responses to occur, in order to build towards an understanding of the divergences between the respective British and German nuclear policies. Exploring more long term processes of incumbent nuclear technology in the Germany and the UK requires further literature related to stability and change within socio-technical regimes.

Factors Bearing on Nuclear Discontinuity in Germany and Continuity in the UK

This section introduces the particular criteria utilised to interrogate the cases of the German and UK nuclear policies. It is developed both through a discussion of literature relating to key aspects of 'innovation journeys' and transitions, such as lock-in and path dependency, and also discussions of key dimensions of factors pertaining to nuclear power more specifically. Given the emphasis on the empirical case studies occupying most of this paper and the following discussion, the authors are aware that the brevity of the discussion of key literature related to directions of innovation journeys does not do justice to the richness of this literature, however, for reasons of space these discussions are kept brief. Through the establishment of wide-ranging criteria related to nuclear power and innovation pathways, the key factors requiring further exploration related to how incumbents in arguably stronger positions in Germany are destabilised, whilst those in the UK in arguably more challenging circumstances maintain positions of power, are identified.

A number of distinct concepts have been developed in order to understand the ways in which transformation is inhibited in socio-technical systems and incumbency is maintained. These include 'autonomy' (Winner, 1980), 'lock in' (Cowan, 1990), 'path dependency' (Arthur, 1994), 'entrapment' (Walker, 2000), and 'obduracy' in 'socio-technical imaginaries' (Jasanoff & Kim, 2009). More recently, notions of 'incumbent strategies' have been developed, adopting political-economic perspectives to analyse the 'resistance' of incumbents to the diffusion of alternative technologies (F. W. Geels, 2014; Smink et al., 2013). Similarly recent attention has turned towards understanding how such path dependent configurations can be 'destabilised' (Turnheim &

Geels, 2012), as well more recent attention to the active discontinuation of well-established socio-technical systems (Stegmaier & Kuhlmann, 2013).

Lock-in and path-dependency are focussed on here to draw attention to economic, technological, and institutional dynamics which form barriers to transformation and sustain incumbent positions within socio-technical systems. As Geels et al (2008: 522) illustrate, the lock in mechanisms which perpetuate incumbent positions for existing technologies include 'periods of increasing return', 'learning by doing', 'scale economics', 'favourable regulations', 'sunk investments' and 'vested interests'. These factors can contribute to the 'lock-out' of alternative technologies (Delrio & Unruh, 2007), and from an economic perspective it follows that the greater the levels of industrial strength, sunk capital, Research and Development expenditure, stronger networks, and more economically efficient a certain sector is, the stronger the tendencies towards path-dependency and lock-in (ibid).

However, focussing on socio-technical regimes also draws attention to other crucial factors including struggles over 'framing' of a particular technological artefact taking place in the public domain (F.W. Geels & Verhees, 2011) which influence the direction of a particular innovation journey. Also crucial are 'discursive struggles' in the policy domain (Kern, 2012), and the role of social movements in influencing technological selection. This relates more to the political contestations taking place within innovation journeys (Meadowcroft, 2009), opening traditional evolutionary economic approaches up to a wider analysis involving a wider set of political and cultural factors. From the perspective of Science, Technology Studies (STS), the cultural significance of the national political contexts in which technological development takes place has been explored using concepts of 'socio-technical imaginaries' (Jasanoff and Kim, 2009) and 'civic epistemologies' (Miller, 2005). Identifying this as an understudied line of enquiry, these frameworks examine the relationship between scientific knowledge and political institutions including the state (Jasanoff & Kim, 2009). Understandings of socio-technical imaginaries highlight how repeated patterns of decision-making and technological commitments remain entrenched beyond the levels of individual regimes, pervading the entire domain of public policy related to science and technology.

In terms of examining features of nuclear power itself and assessing why particular countries make the decisions they do with regard to nuclear power, the main criterion used have essentially been limited to climate change mitigation and energy security, energy demand issues, and public opinion (Sovacool & Valentine, 2012). It is fair to say that social science research on nuclear power has been slow to catch up in terms of the analysis of a range of broader issues outside of these three dimensions, and in particular, interrogation of factors relating to the political dynamics and vested interests that contribute to choices over nuclear energy remains sparse (Sovacool, 2011). This stands in stark contrast to previous rounds of nuclear development where a range of political and democratic issues formed a focal point of analysis (Blowers & Pepper, 1987; Byrne & Hoffman, 1996; Camilleri, 1984; Eckstein, 1997; Kitschelt, 1986; Massey, 1988; O'Riordan, 1988; Purdue, Kemp, & O'Riordan, 1984; Schrader-Frechette, 1980).

The criteria established to contrast the cases of the UK and Germany thus seek to encapsulate concerns relating to a broad range of factors including technical, economic, political and cultural domains. Verbruggen et al (2014) assessed what they referred to as the 'actual' sustainability of nuclear power by developing a set of 19 criteria extending beyond the usual preoccupation with carbon alone. Their criteria are based around four categories including environmental/ecological, economics, social, and governance/ policy (politics). These include concerns such as the wider economic framework in which nuclear is proposed in consideration that nuclear struggles to operate in more liberalised energy markets (Kahn, 1997; MacKerron, 2004). Hultman (2011) identifies other key dimensions of nuclear technology which can be used as useful criteria including military-related nuclear activity and how competitive a countries particular nuclear industry in terms of general performance and economic efficiency. Combining insights from the literature related to socio-

technical regimes as well as the specificities of nuclear technology the following criteria and parameters were selected in order to contrast the cases of German and UK energy policy. Each individual criterion represent a reasonable consideration which, all else being equal, might be expected to exert an important influence on the prospects for the discontinuation of nuclear trajectories and its substitution by alternative energy strategies. Taken together, then, the set of criteria as a whole constitute a group of considerations that might collectively be taken to assume a more significant explanatory value, than any other factor.

Outline of Criteria

<i>1:0 General Market Conditions In The Two Countries</i>	<i>1:1 Market coordination</i> <i>1.2: General public spending</i>
<i>2:0 Degree of penetration of nuclear in the electricity generating mix</i>	<i>2.1: Top ten nuclear generating countries</i> <i>2.2: Dependency on Nuclear power</i>
<i>3:0: the relative strengths of the nuclear engineering sector in terms of performance in manufacturing and operational equipment supply and associated industrial lobbies</i>	<i>3.1: Performance of plants</i> <i>3.2: Comparison of constitution of respective nuclear industries in Germany and the UK</i> <i>3.3: Research and Development in nuclear power</i> <i>3.4 Share of global nuclear Patents (national aggregate and by company)</i>
<i>4.0: Relative magnitudes and costs of available national renewable resource potentials</i>	<i>4.1 Overall renewable Resource</i>
<i>5.0: The scale of national industrial capacities and interests to address renewable energy supply</i>	<i>5.1: Overview of renewables growth in Germany and the UK</i> <i>5.2: Research and development</i> <i>5.3: General Narratives of renewables policy</i> <i>5.4: Industrial strength – equipment supply industries</i>
<i>6.0 relative scales of military-related nuclear activities and associated industrial interests</i>	<i>6.1 nuclear weapons capabilities</i> <i>6.2 Nuclear Ballistic Missile Infrastructure</i> <i>6.3 Nuclear propelled submarines</i>

	<p><i>6.4 Military-related equipment supply industries</i></p> <p><i>6.5 Stated future plans for military renewal</i></p>
7.0: Relevant characteristics of general national political institutions and elite cultures	<p><i>7.1: centralisation / decentralised political system</i></p> <p><i>7.2: Prominence of Green Party</i></p> <p><i>7.3: prominence of consensus/deliberative-style politics</i></p>
8.0: Broader Presence and activity levels of relevant social movements	<p><i>8.1: generalised public opinion on nuclear power</i></p> <p><i>8.2: Baseline in public attitudes on nuclear: confidence in nuclear industry</i></p> <p><i>8.3 Baseline in public attitudes on nuclear: perception of nuclear risk</i></p> <p><i>8.4 Maximal Scale of protests</i></p> <p><i>8.5 intensity of public debate including media mentions</i></p>
9.0 Comparison of democratic quality	<p><i>9.1 Majoritarian Vs consensual</i></p> <p><i>9.2 Democracy barometer rating</i></p> <p><i>9.3 Economist intelligence Unit rating</i></p> <p><i>9.4 Global Democracy ranking</i></p>

EMPIRICAL APPLICATION OF CRITERIA TO CASE STUDIES

1:0 General Market Conditions In The Two Countries

1:1 Market coordination

A 'varieties of capitalism' analysis (Hall and Soskice 2001) identifies paradigmatic differences in economic and market conditions in the UK and Germany. In this view, Germany is the main example of a '*coordinated economy*'. This entails a strong role played by the state in intervening to steer markets towards desired ends. Indeed, proactive support of a variety of innovative energy technologies, suggests Germany as a possible example of an even more strongly defined 'entrepreneurial state' (Mazzucato, 2013). A particularly salient example here is Germany's direct involvement with the promotion of renewables, at a stage before they were widely considered 'commercially viable'. This contrasts with the UK, which a varieties of capitalism analysis holds to be (with the USA) a paradigmatic example of a '*market economy*'. In this case, the prevailing trend is

for lesser degrees of coordination from the state, allowing private investment and ‘price signals’ to be not just the main instruments – but also key drivers – of policy.

Germany was in 1999 one of the first countries to tax fossil fuels. With the landmark Energy Act of 2000, Germany was the first to introduce what was to become the internationally highly influential policy of feed-in tariffs (FiTs) for renewable energy. This involved major interventions to ensure that European Commission policy interpreted existing law such permitted these measures to avoid penalisation as ‘State Aids’ (Liebmann, Resch, Pause, Kahles, & Lamprecht, 2014; Scrase & Mackerron, 2009). Thus there has been substantive market intervention in Germany on this issue for well over a decade.

The picture contrasts quite drastically in the UK. Here, the introduction of the 1989 Electricity Act under Prime Minister Margaret Thatcher was a step change in the British electricity sector that also was later to prove internationally formative. The UK has long been reluctant to intervene in the market to anything like the extent seen in Germany. By contrast with the direct promotion of particular technologies under the German FiTs policy, the UK favoured the more ‘hands off’ ‘market based’ approach of the Renewables Energy Obligation (Mitchell et al., 2006). The UK only implemented FiTs for renewables eight years after Germany’s EEG.

1:2 General Public Spending

Over the past 20 years, the ‘coordinated’ nature of Germany’s economy has seen significantly greater levels of general public spending as a proportion of GDP than is the case in the liberalised market economy of the UK. In 2011, public expenditure accounted for 44% of German GDP, with the same figure for the UK at 39% (Cottarelli & Schaechter, 2010). In the year 2000, German public spending increased to 47% of GDP, with the corresponding figure for the UK reducing to 37% (ibid). This general picture is compounded by specific figures for energy R&D considered later in this article, but is in its own right potentially relevant to the general conditions for transformation.

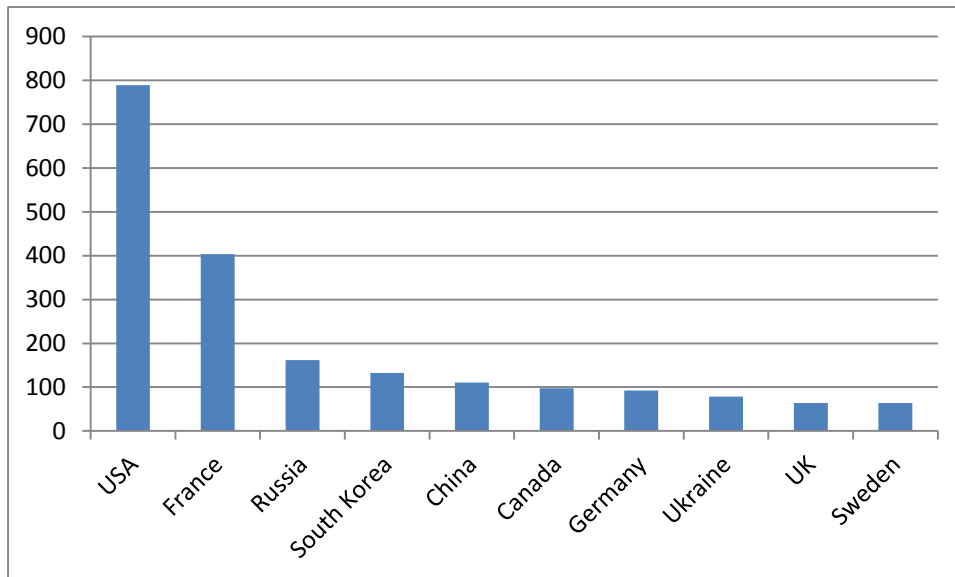
Given the upfront capital costs and history of strong state involvement and spending with regards to nuclear power, it could be argued that Germany’s higher levels of public spending and state intervention in markets would favour the continuation of nuclear power.

2:0 Degree of penetration of nuclear in the electricity generating mix

2.1: Top ten nuclear generating countries

The graph below shows in absolute terms that Germany produced significantly more electricity from nuclear power in 2013 than did the UK, ranking seventh in the world for total nuclear generation, compared with the UK positioned at ninth. This is despite having closed 8 reactors following events at Fukushima in 2011.

Figure 1: Top ten nuclear generating countries, 2013 (billions kWh)



Source: Nuclear Energy Institute (2014)

2.2: Dependency on Nuclear power

The picture is even more pronounced when considering the longer timeframes over which have developed the divergent cases of the UK and Germany. Figure 2 below outlines some key further differences that applied prior to the Fukushima accident, in respect equally of the absolute scales of respective nuclear electricity production and the relative degrees of national dependence on nuclear power. Figure 3 shows that the significantly greater scale of the German nuclear electricity production extends back into historical periods well before the development of the German Energiewende. Even as late as the Fukushima accident in 2011, the nuclear share of total electricity production was 25% in Germany and 19% in the UK and the total amount of electricity produced from nuclear in Germany was more than double that in the UK.

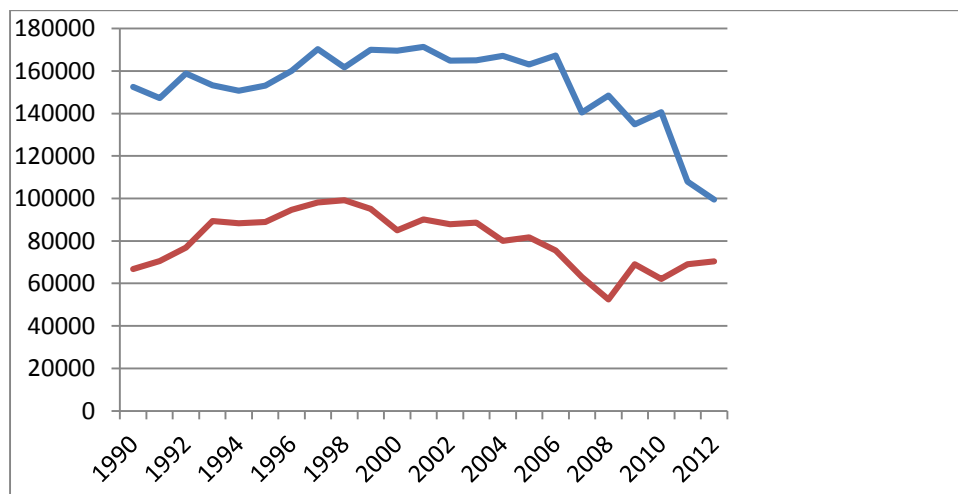
Figure 2: Indicators of nuclear size and penetration in the UK and Germany

	GERMANY	UK
World ranking in nuclear electricity production (2010)	5 th	9 th
Total nuclear capacity MWe (2010)	20,339 MW	10,038 MW
Historic maximum nuclear production in one year (GWh)	171,305 (in 2001)	99,486 (in 1998)
% share of electricity generation in overall mix (2010)	22.2%	16.27%

Historic maximum % share of nuclear in generation mix	31%	28%
Number of reactors in 2010	17	16
Average size of individual reactors (MW)	1048 MW	581 MW

Source: data gathered from International Energy Agency statistics Database (2014) and World Nuclear Association (2014)

Figure 3: German and UK Production of nuclear power (GWh) 1990-2012



Source: IEA Statistics database (2014)

It is clear from this both in relative and absolute terms, that the nuclear generation has long been significantly more important in Germany than in the UK. Considering this particular factor in isolation then, it might reasonably be inferred that Germany would face far greater challenges than the UK in seeking to close its nuclear power facilities. On these specific grounds, any ceteris paribus assessment of likely relative degrees of lock-in, would consider transformation in Germany correspondingly less likely than the UK.

3.0: the relative strengths of the nuclear engineering sector in terms of performance in manufacturing and operational equipment supply and associated industrial lobbies

3.1: Performance of plants

Figure 4: General performance of nuclear plants, load factor indicators.

	Germany	UK
Number of reactors in list of top 20	5	0

performing reactors in the world		
Average load factor of reactors	85%	74%

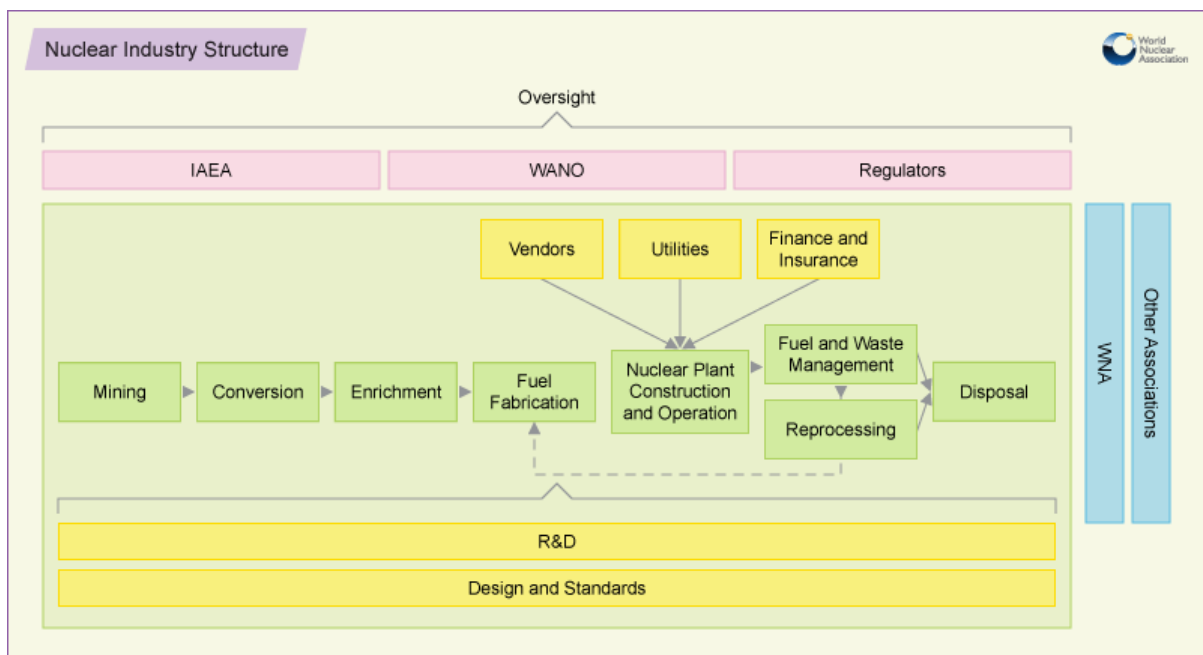
Source: World Nuclear Association (2014)

The most crucial general measure of performance in the nuclear generating industry is load factor, referring to actual output as a fraction of total possible output. In these terms, the 13 highest performing nuclear power plants worldwide are sited in only 3 countries: 6 in South Korea, 5 in Germany, and 2 in Finland (Thomas, 2005). German reactors hold the first eight positions in *Nuclear Engineering International's* league table of the reactors that have generated the most electricity to date (World Nuclear News, 2008). Load factor is an important proxy for manufacturing and equipment quality, because it is dependent to a large extent on system engineering. So it is relevant in this regard, that, the top three lifetime electricity generators (TWh) at the end of 2011 were all in Germany – Grafenrheinfeld, Grohnde, and Philippsburg 2 (Nuclear Engineering International, 2012). The best performing reactor in the world in terms of average lifetime load factor is Grohnde in Germany (ibid). On many other indicators including construction costs, capital costs, operating costs, and load factor, Germany is considered to host one of the best performing nuclear engineering industries in the world (Bruninx et al., 2013). This is in strong contrast to the UK, where, as documented by the Environmental Audit Committee report on *Keeping the Lights On* (2006) the UK performs strikingly poorly overall on most international comparisons related to plant performance.

3.2: Comparison of constitution of respective nuclear industries in Germany and the UK

This section provides a broad overview of the different aspects of the nuclear supply chain that are present in Germany and the UK. As background, figure 5 below summarises relations between these key nuclear industrial activities:

Figure 5: aspects of nuclear supply chain



Source: World Nuclear Industry Association (2014)

The focus in this analysis is nuclear power itself (rather than ancillary industries). And it can be seen from the above diagram that this holds a central place in the industry structure. Indeed, this is the activity that accrues the vast bulk of the exogenous revenue streams that sustain the sector as a whole. So, it is reasonable to begin an inspection of the industrial strength of each country's respective overall nuclear industry with those activities that relate most directly to the operation of nuclear generating plant.

Figure 6: main nuclear industry in Germany and the UK

	Germany	UK
Reactor Vendor companies	Siemens one of the most successful reactor vendors in world, annual turnover in 2000 of £70 billion. Reactor sales to Brazil, Iran, Argentina and Eastern European states until abandoning nuclear operations in 2012	No nuclear reactor vending since the 1960s when UKAEA sold a total of 2 reactors to Japan.
Companies involved in operation, ownership and sale of nuclear electricity	RWE, E.ON, EnBW, all international nuclear operators headquartered in Germany	There is no UK headquartered company that is a major nuclear power utility company
Total commercial Turnover	£10 billion	£4 Billion
Nuclear labour force in civilian nuclear power (directly employed by nuclear companies)	38,000 (civilian nuclear power excluding waste disposal)	30,000 (excluding waste disposal such as Sellafield that employs 10,000 people)

Sources: (Cogent, 2009; DECC, 2013; Environmental Audit Committee, 2006)

It must also be added, however, that the UK does have substantial nuclear expertise in other areas. In particular, Rolls Royce manufacturers component parts for nuclear plants. Rather than new build however, the UK's nuclear industrial expertise now lies mainly with 'backend' processes, including decommissioning and waste disposal, as seen in the figure below.

Figure 7: Other areas of nuclear activity

	Germany	UK
Provision of components and systems, control technology	Advanced Nuclear Fuels, Bilfinger Berger Power Services, Nukem Energy (<i>note: These companies are speciality nuclear companies</i>)	Rolls Royce (safety-critical instrumentation and control technology), AMEC, Thompson Valves, Glowserve Worcester controls, Doosan Babcock
Decommissioning and waste disposal	GNS Gesellschaft Für Nuklear-Service, Nukemtechnologies	Magnox LTD, Energy Solutions, Sellafield LTD, Dounreay Site Restoration LTD, Cavendish Nuclear Waste Management

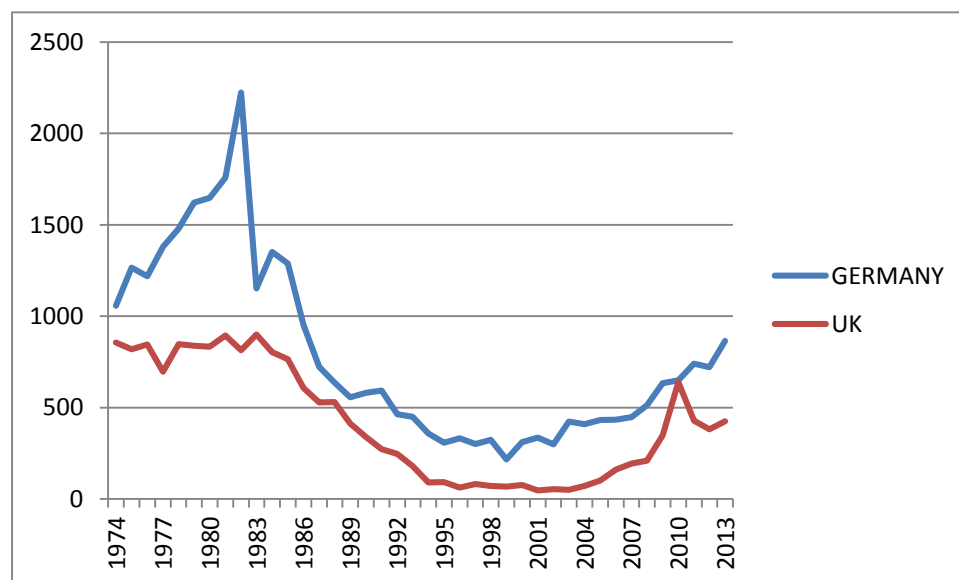
Fuel Enrichment and associated technology	Urenco (uranium enrichment consortium between Germany, Netherlands, and the UK)	Urenco
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3.3: Research and Development in nuclear power

Research and development in nuclear fission also provides an interesting basis for comparison between the UK and Germany. The UK used to be a world leader in the development of fission technologies, with an R&D workforce in excess of 8,000 and an annual R&D budget of over £300m/year in the 1980s. At present the human capacity is less than 600 and funding less than 10% of the historical level (House of Lords Science and Technology Select Committee, 2011). The UK spends around 1.8% of its energy R&D budget on fission research. This contrasts strongly with Germany, which as late as 2009 (despite a long term policy of phasing out nuclear power), still spent 7.3% of its energy R&D on nuclear fission technology. Of the corresponding figures for the UK, the Birmingham Policy Commission Report (2012: 80) found that “[t]his level is more commensurate with a policy to phase out nuclear energy than an ambition to build new nuclear plants”.

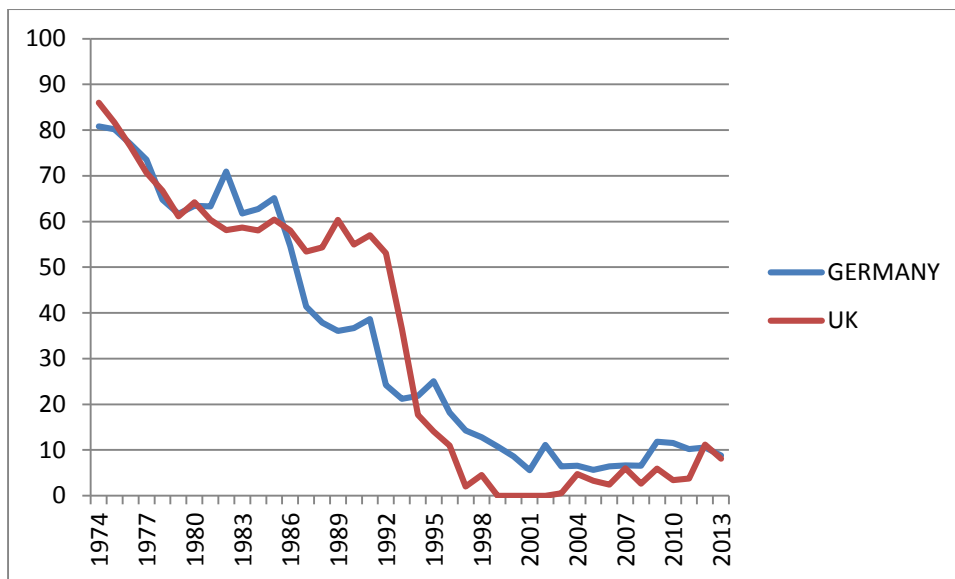
Germany has consistently spent more money on nuclear-related R&D than the UK. The graph below charts historic UK and German expenditure on nuclear R&D. The following graph which shows the nuclear proportion of total civilian energy R&D spend in each country:

Figure 8: UK and German civilian nuclear R and D expenditure, 1974-2013



Source: IEA (2014) R and D Database

Figure 9: nuclear R and D spend as a percentage of overall energy R and D spend



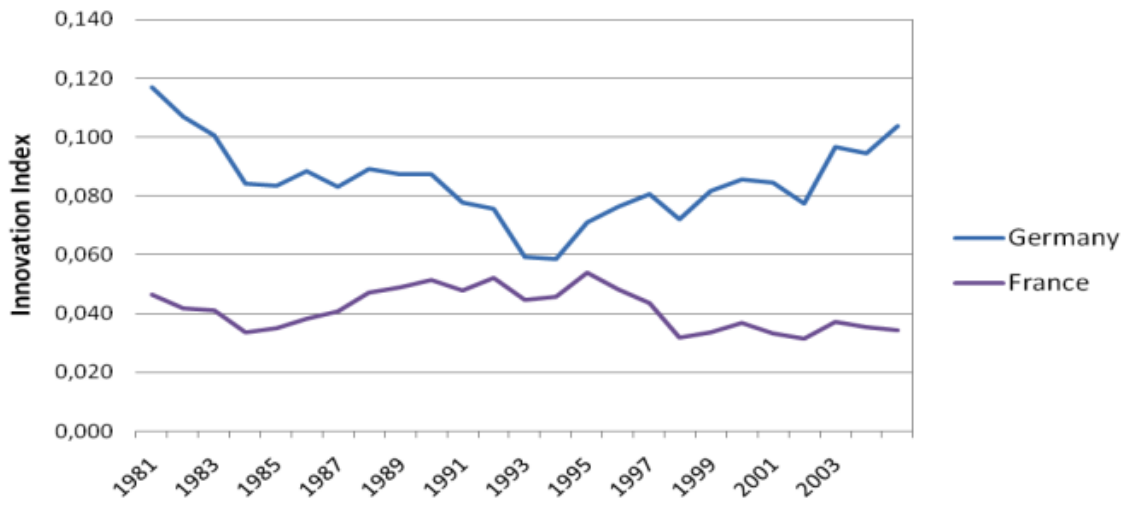
Source: IEA (2014) R and D database

What is notable, is that despite phase-out being set in motion since the 1990s, German nuclear spend as a share of overall energy R&D remains higher than the UK between 1993-2013. Regardless of nuclear policies, then, the respective R&D pictures can be summarised as follows: the UK resembles in this respect a country that is committed to a phase-out of nuclear power, whilst Germany's expenditure resembles a country that has a resurgent programme (Birmingham Policy Commission, 2012). As emphasised in a Carbon Connect report chaired by pro-nuclear policy advocates Baroness Bryony Worthington and Charles Hendry MP, "despite the return of new nuclear power to Government plans for power sector investment since 2007, a 2013 review by the Government's then Chief Scientific Advisor found that the institutional landscape and funding still reflected the policy environment of the 1990s and early 2000s" (Lévêque, 2014: 25). What is more, as Figure 7 shows, nuclear activity in the UK is focussed on "the past (decommissioning) the present (safety and performance) and the very long term future (fusion), but not on developing new nuclear fission technologies or fuel cycles for the medium to long term" (ibid: 25). This is not indicative of any significantly pressure from vested interests in R&D, for attachment to nuclear power in the UK than Germany.

3.4 Share of global nuclear Patents (national aggregate and by company)

Another indicator of the relative strength of nuclear engineering activity, is the volume of patenting for nuclear fission technologies. Whilst there are many pitfalls in seeking to use patent data as indicators (), there are nevertheless some striking results. The graph below compares German patenting activity of Germany with that of France, as arguably the long-run historic global leader in this field (Hecht, 1998). Despite the contrast between a long-term nuclear phase out in Germany and a continued globally-leading commitment to nuclear power in France (for instance, at 75% of electricity generation), this 'innovation index' approach suggests Germany nuclear patenting activity actually increased from 1990 onwards despite policies putting in place the beginning of nuclear phase out following the Chernobyl disaster.

Figure 8: German and French Innovation Index

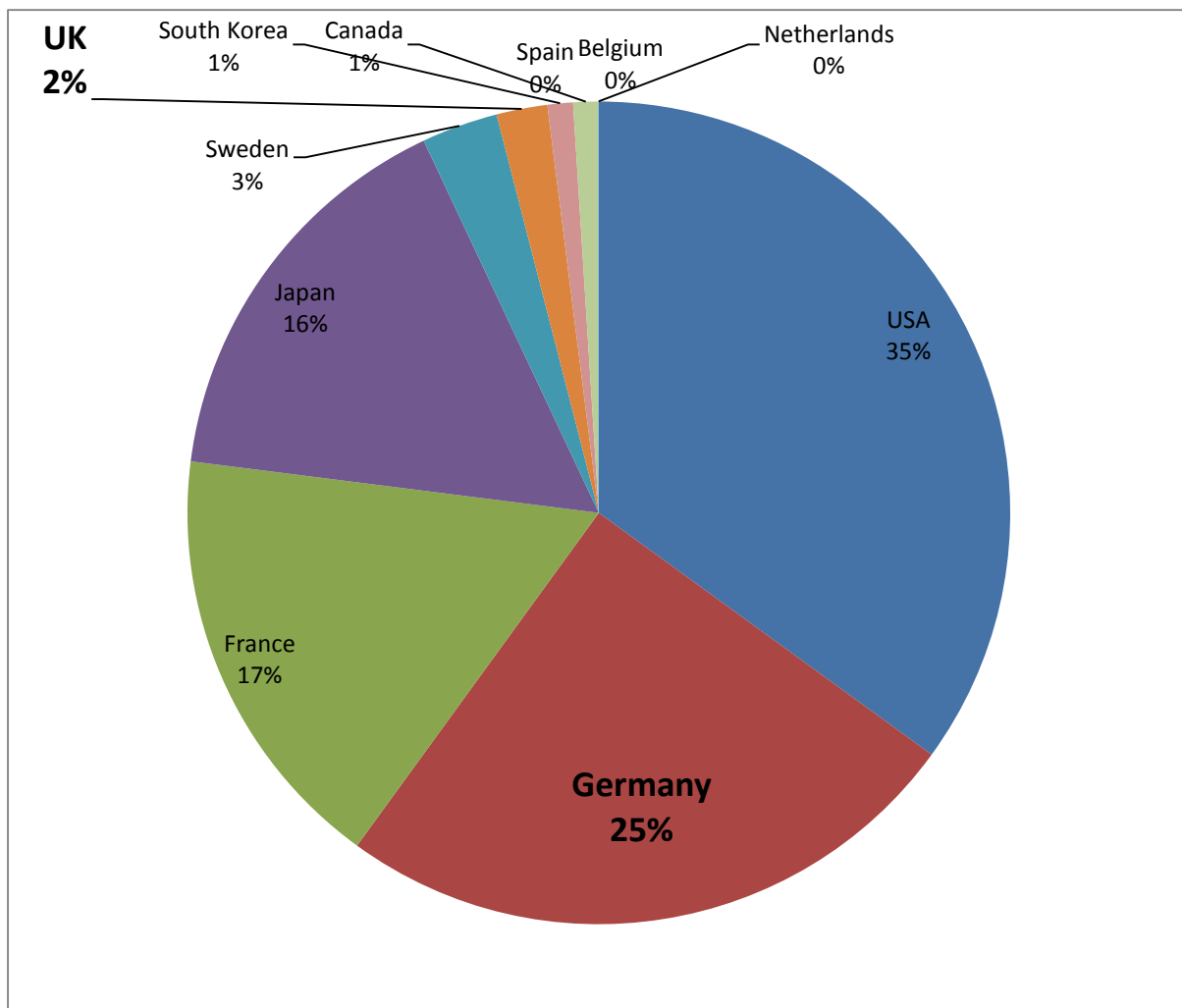


(Lévêque, 2010)

As described by the author, “Despite this decision [to phase out nuclear power], Germany seems to innovate more in nuclear technology than France. It has a better innovation index (as defined as the number of yearly national patent applications in nuclear technology divided by the number of yearly national patent applications in all technological fields) than France.” (Lévêque, 2010).

Another important comparison relates to the share of total patents relating to nuclear power over the past few decades between countries. As seen in Figure 9, Germany has the second largest share of patents following the USA, with 25% of patents, whilst the UK has 2% of the patent share. What can also be seen is key differences in terms of what are considered to be the most innovative companies related to the nuclear sector. In this regard, Germany also substantially outperforms in terms of the position of German-based companies in the list of most patent applications by country as seen by the figure below.

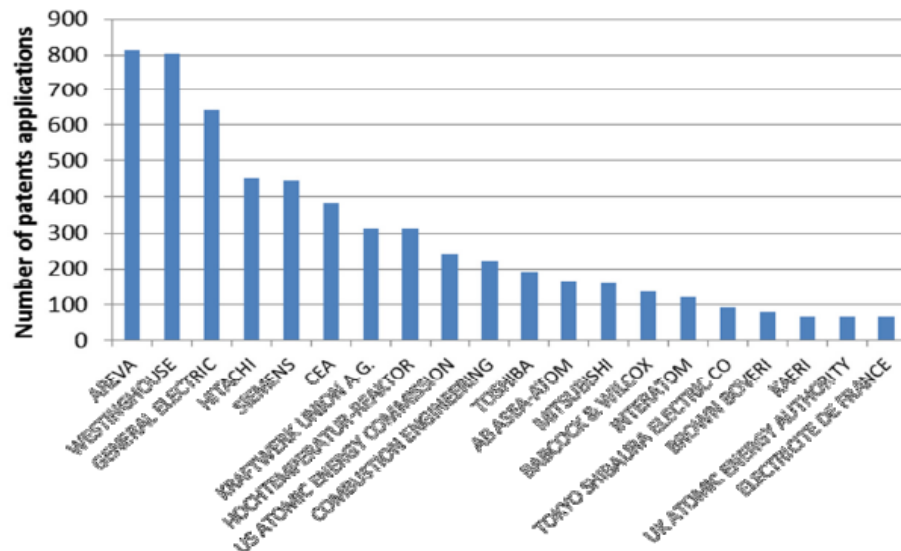
Figure 9: Share of nuclear patents by country



Source: Berthélemy (2012)

Germany has the second largest share of patents following the USA, with 25% of patents, whilst the UK has 2% of the patent share. What can also be seen is differences in terms of what are considered to be the most innovative companies related to the nuclear sector. Germany also substantially outperforms in terms of the position of German-based companies in the list of most patent applications by country as seen by the figure below.

Figure 10: patent applications for civilian nuclear power by country



Source: Berthélemy (2012)

Three German companies (Siemens, Kraftwerk Union A.G, and Hochttemperatur-Reaktor) can be found among the top ten in the world for nuclear patent applications. The UK Atomic Energy Authority, has the second lowest number of patent applications of the surveyed organisations, whilst the UK firm Babcock and Wilcox is higher up, at 7th from bottom. Babcock and Wilcox, is the UK's largest defence contractor after BAE Systems and Rolls Royce, and much of its activity relates to military nuclear technology developments.

In concluding this overview of key features of nuclear industry activity in the Germany and the UK, Table X (below) summarises the overall picture.

Figure 11: Summary table of Nuclear industry in the UK and Germany

	Germany	UK
Total R and D spent on civilian nuclear 1974-2012	€31.4 Billion	€16.6 Billion
% of total Energy R&D expenditure dedicated to civilian nuclear power, 1974-2013	47%	51%
Amount spent on nuclear R&D in 2010	€11.7 million	€3.4 million

% of overall expenditure of Energy related R&D in 2010	11.5%	3.4%
Approximate number of patent applications 1974-2008	1050	250
% total of civilian nuclear patent applications 1974-2008	25%	2%

4.0: Relative magnitudes and costs of available national renewable resource potentials

4.1 Overall renewable Resource

An important consideration when thinking about low carbon technological alternatives, are the potential reserves available in the respective countries, and the costs and operational ease with which this can be harnessed. This is a separate matter, to the relative capacities of the respective renewable industries, which is a distinct criterion. In these terms, then, the renewable resource base is best understood as the energy that might potentially be utilised under comparable assumptions concerning resource availability and economic costs of exploitation. This involves both theoretical and technical considerations that are well explored in various intensive studies conducted across different European countries on a comparable basis (European Renewable Energy Council, 2010). The overall position as between Germany and the UK is quite unambiguous and – again – quite surprising in relation to the pattern of developments in this field.

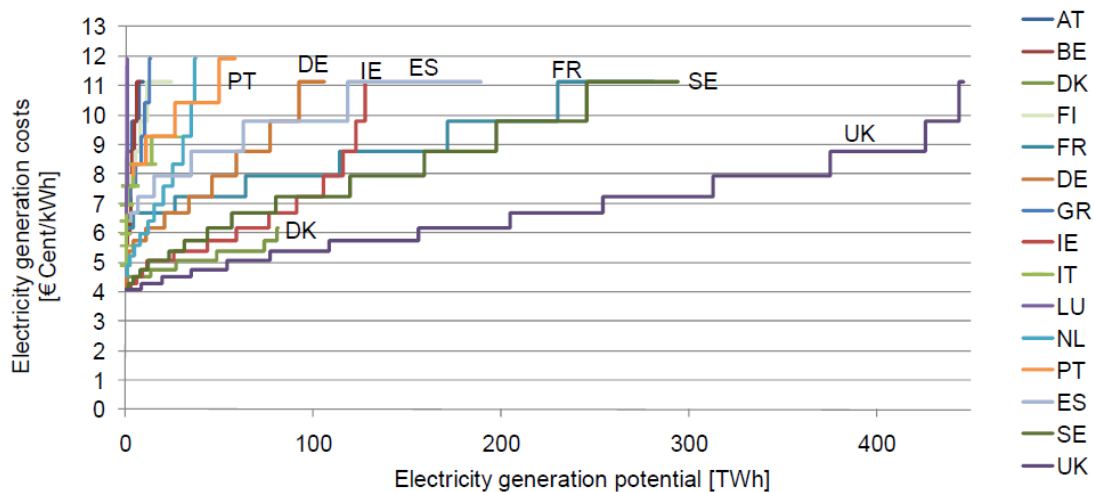
The UK has 40% of the total economic wind energy resource in Europe. It is repeatedly and without controversy assessed to enjoy the best wind resources on the continent (HM Government, 2014). Scotland alone has 25% of the total for the whole of Europe (The Scottish Government, 2014). As the ‘windiest place in Europe’ (EDF Energy, 2014), the UK also has vast potentials for viable offshore wind power. With one of the longest coastlines in Europe at an estimated length of 12,429KM (CIA, 2014). the picture is similar for wave and tidal power, where the UK alone is assessed to hold 50% of the total economic European potential (HM Government, 2014). The Severn estuary alone presents one of the most attractive sites in the world for development of large scale tidal power. In the case of hydroelectricity, most feasible sites in the UK are considered to already be utilised (DECC, 2009), with the technical challenge lying simply (and more marginally) in plant improvement. For these resource reasons, Wilson (2012) notes that a series of UK government reports in the 1970s identified the UK renewables industry as being potentially the cheapest in Europe, leading to a series of R and D proposals that will be discussed in the next criteria.

For its part, Germany has a significantly smaller share of the European economically-exploitable resource for wind, wave and tidal energy. The relevant figures stand at around 20% for wind energy, around half that of the UK’s potential. The German coastline is an estimated 2,389km (CIA, 2014) substantially smaller than the UK, so there in absolute terms there is less potential for offshore wind, wave and tidal development – the latter especially less favourable through the lack of exceptionally attractive sites like the Severn estuary. Indeed, (as will be discussed further) Germany has lagged behind the UK with regards to the development of offshore renewables, only in the past few years experiencing significant growth in this sector, a growth that has become troubled in the past two years (Fröhlingsdorf, 2013). Southern Germany has significant solar power potential, where one of the world’s largest solar parks is located (Renewable Technology, 2014).

An important factor to also consider is the ‘Cost-resource Curves’ of renewable resources of the respective cases of Germany and the UK. This combines economic data related to wind turbines, the assessment of the

number of 'full load hours' calculated by wind speed in a location at hub height, as measuring the available land that is suitable for deployment that along with wind speed, is used to calculate the 'wind potential' of a particular country. Thus an idea of potential amounts of production of wind power and the cost of achieving this amount is projected. The graph from Held (2012) below displays comparative cost-resource curves for on-shore wind across European countries:

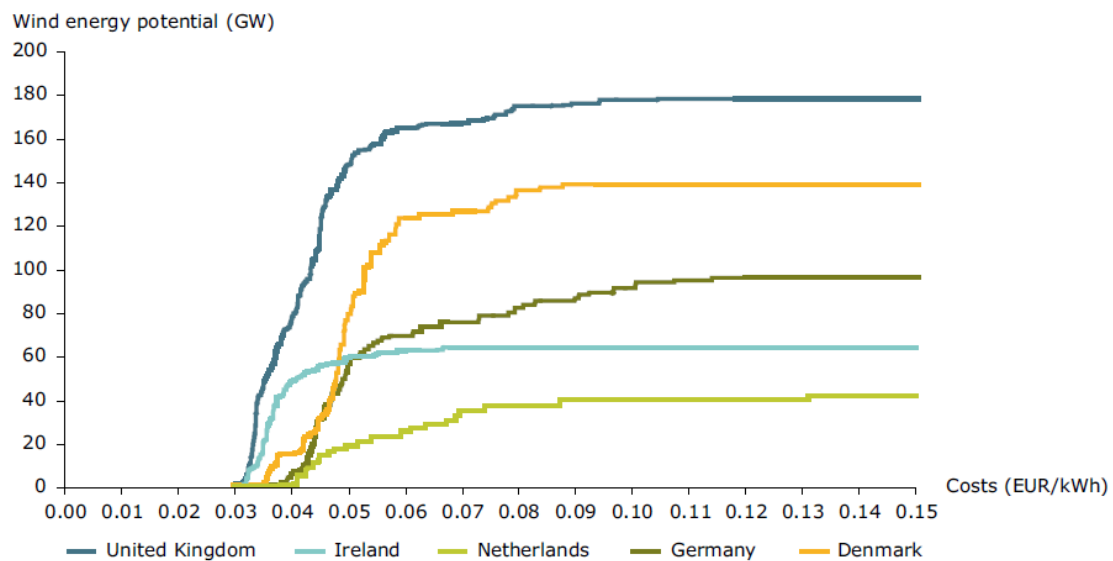
Figure 12: Cost resource Curve for onshore wind in European countries



Source: Held (2010)

What can be seen is that the UK has the largest potential of exploitable wind resource as well as the cheapest wind resource in the Europe, outperforming Germany. This is also the picture for offshore wind as seen below:

Figure 13: Cost resource curve for offshore wind resource in European countries



Source: Source: European Environment Agency (2009)

Some parts of the UK have comparable solar resource as Germany yet have not exploited this resource and discrepancies between resource potential and relative costs are small.

Figure: 14: Comparative solar resource and costs for Germany and the UK

	Germany	UK
Mid term potential (GWh)	52393	43040
Capacity potential (MW)	71929	64844
Average Full load hours	728	664
Cost of electricity (min) (€/MWh)	716,0	787,6
Cost of electricity (Max) (€/MWh)	1423,0	1565,3
Cost of Electricity (average) (€/MWh)	970,0	1063,1

Source: Resch et al (2003)

Whilst costs are difficult to ascertain it is well known that the UK possesses the best resource in terms of wave and tidal in Europe:

Figure 15: Wave and tidal potential resource

	Germany	UK
Realisable potential up to 2020 (TWh)	7,73	58,90

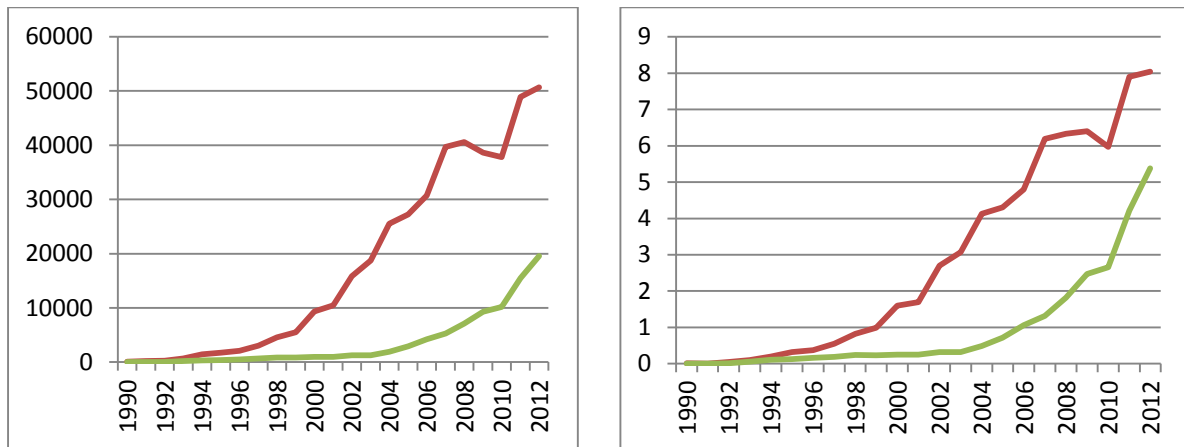
Source: Resch et al (2006)

5.0: The scale of national industrial capacities and interests to address renewable energy supply

This section gives an overview of renewable energy capacities in Germany and the UK and the industrial interests that surround these technologies. This outlines in a series of tables documenting growth in various renewables from 1990-2012 from IEA data in both the UK and Germany, R and D expenditure into various renewables technologies as a proxy for likely support in certain technologies, assessment of constitution of renewables industries and equipment supply industries in each country, and qualitative assessments of general narratives of support for renewables proceeding the growing capacity for renewables.

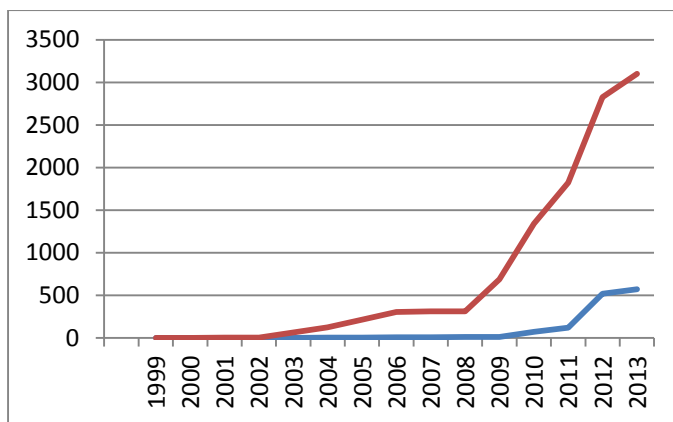
5.1: Overview of renewables growth in Germany and the UK

Figure 16: wind power: Wind power capacity (GWh) **Figure 17: % share of wind in electricity generation (GWh)**



Source: IEA database

Figure 18: Deployment of Offshore wind capacity in Germany and the UK (MW)

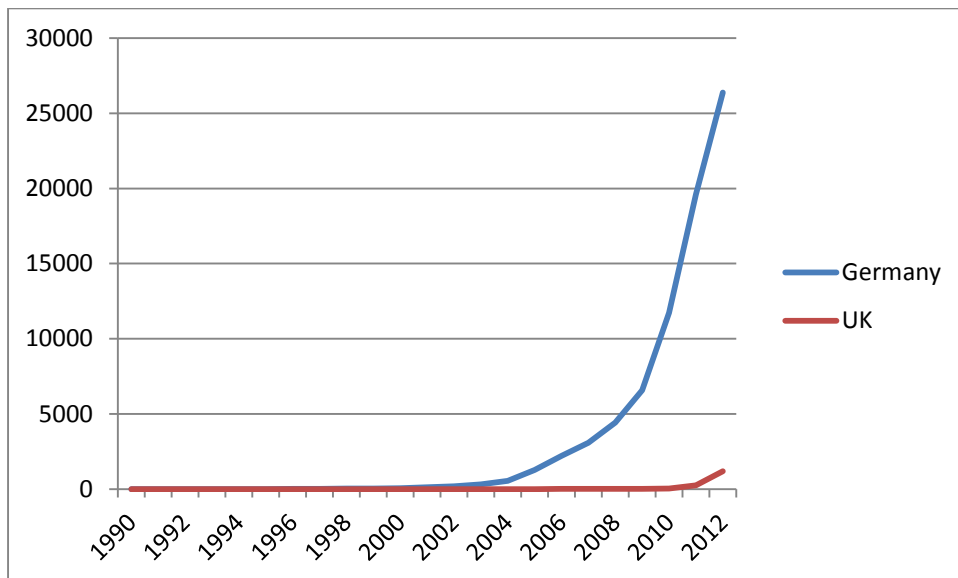


Source: Kern et al (2014); DECC (2014); EWEA (2014)

Solar power

The graph below outlines the growth in solar capacity in both Germany and the UK. Germany again, experienced rapid growth in solar power compared to UK growth only beginning several years after Germany with the Feed in Tariff system for solar established in 2010, 10 years after Germany's Renewable Energy Act.

Figure 19: Solar capacity



Source: IEA database, 2014

Biomass

Germany and the UK have both utilised biofuels and biomass, which have grown as a proportion of electricity production as seen from the tables below. In the UK increasing use of biomass was supported through the *Non-Fossil Fuels Obligation* and then the *Renewables Obligation*, with DECC later implementing Feed-InTarrifs for small scale biomass in 2010. In Germany biomass has been stimulated by the *Electricity Act* of 1990, the *Renewable Energy Act* 2000, and the *National Biomass Action Plan* in 2009.

Fig 20: % bio waste in electricity supply in Germany and the UK

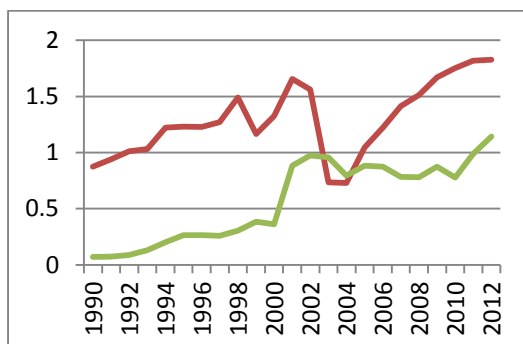
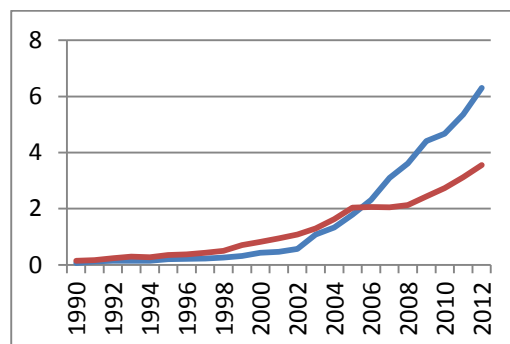


Figure 21: % biofuels in electricity



Source: International Energy Agency database (2014)

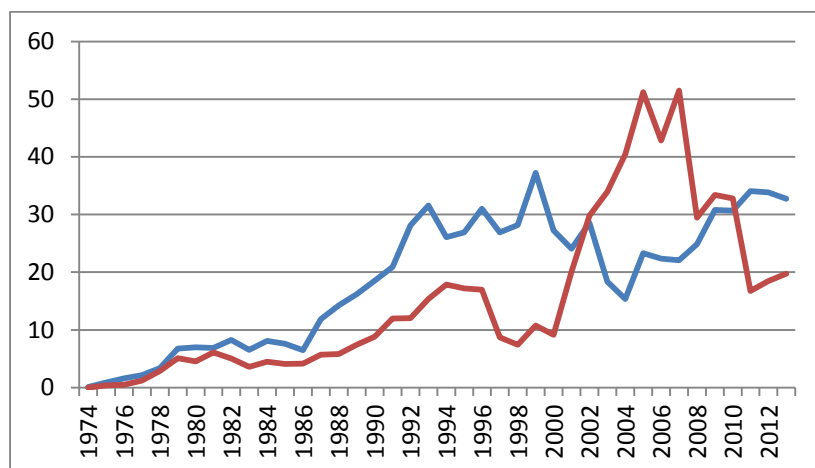
What is undoubtedly clear is that in all technological areas besides Offshore wind development in which the UK is a world leader in terms of total amount of installations deployed, Germany has generally deployed

more renewable energy, beginning in most cases, at a notably earlier stage than the UK. Now the general patterns related to R and D and industry surrounding these trends is looked at.

5.2: Research and development

The figure below traces the percentage share of R and D expenditure as a share of total R and D expenditure on energy, and the table that follows outlines key facts:

Figure 22: % Renewable energy R and D as a share of total Energy R and D



Source: International Energy Agency database (2014)

Figure 23: Total Renewables R and D spend, Percentage of renewable R and D as part of total energy R and D and total civilian nuclear R and D, 1974-2013

	Germany	UK
Total Renewables R and D 1974-2013	€4.5 Billion	€1.5 billion
% Renewables as share of total energy R and D, 1974-2013	13%	9%
% Renewables R and D as share of total nuclear R and D, 1974-2013	29%	18%

The UK devoted a smaller share of energy R and D to renewable energy sources until 2002 when the UK rapidly increased its share of energy R and D spent on renewables. This declined once again, due to cuts in public spending occurring around 2010. What is most interesting from our perspective however, is that in the 1970s through the early 1980s the share of energy R and D spent on renewables by the UK and Germany were comparable before Germany began to rapidly increase its R and D spend on renewables following reorientation of spending due to policy responses to Chernobyl. It is crucial to focus also on more narrative based accounts surrounding the period before the German 'take off' in renewables began, as well as focussing on R and D spending.

This focusses on support for renewables in the general policy environment. As (A. Smith & Raven, 2012) point out, analysis of socio-technical change often identifies ‘niches’ or ‘protective spaces’ in terms of Research and Development priorities without sufficient explanation of how such spaces arise and how they are ‘protected’. The contested nature of emerging niches are often missed. The figures below show R and D funding in renewable energy. Activity in both Germany and the UK was sparked initially by the Oil Crisis of 1974. The countries both took different approaches:

Figure 24: Ocean Energy R and D, UK and Germany

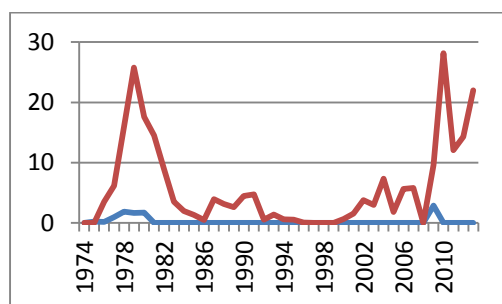
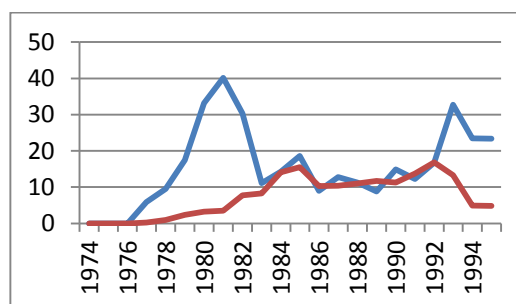
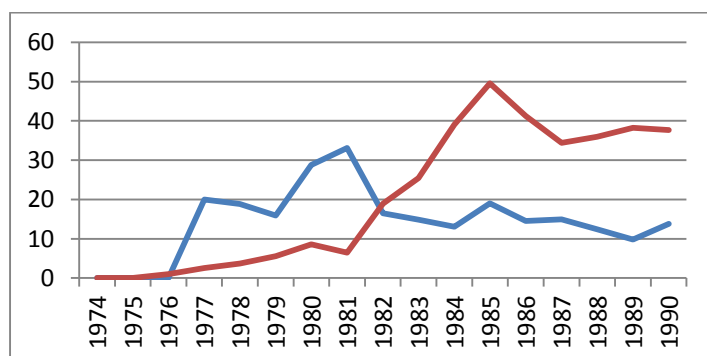


Figure 25: R and D expenditure on wind energy



During the 1970s in the UK there was substantial public investment in ocean energy whilst Germany was negligible. Germany began to invest substantially in wind energy R and D in 1977, with a notable peak of spending the equivalent of €40 million in 1981, before a rapid decrease in spending. It should be noted that throughout the 1980s, the UK was spending on par, or in some years, spending more than Germany throughout the period from 1982-1992 a crucial formative period preceding the ‘take off’ of the *Energiewende*. In terms of R and D spend on wind energy as a percentage of total renewables R and D funding the UK was devoting a greater share of its R and D resource to wind energy through the 1980s before R and D spend on energy was considerably reduced in the 1990s:

Figure 26: % wind energy R and D spend as share of overall renewable R and D funding, 1974-1990.



Thus the UK was spending at similar levels throughout the 1980s and devoting a greater share of their renewables budget to wind power in the 1980s as Germany was, despite Germany’s initial steep and short lived increase in renewables spending at the end of the 70s. The two countries are now assessed in more detail in terms of narratives surrounding the evolution of renewables policies in Germany and the UK.

5.3: General Narratives of renewables policy

Figure 27: General narratives of renewables policy in Germany and the UK

	Germany	UK
Phases of renewable energy policy support	<p>Phase 1 (1974-1989): The first 15 years of RES-E policy after 1974 were devoted to R&D. Market creation measures only came after 1988.</p> <p>Phase 2 (1989-onwards): Government reorientation towards market penetration by means of technology specific investment programs and feed in tariffs (1,000 solar roofs program and 100-250MW. Germany's energy market was liberalised in 1998, however FITs continued to be refined through the Energy Act 1999, leading to rapid growth in wind energy and later solar PV.</p>	<p>Phase 1 (1974-1989): Government support for technical innovations for wave energy in the 1970s and large wind power in the 1980s</p> <p>Phase 2 (1989 onwards): Privatisation of energy in Electricity Act. Phasing out of government support for renewables during the 1990s due to expectation of private finance filling the gap, which did not occur. Non-fossil fuels obligation and later Renewables obligation favoured over technology specific technologies, and more direct market interventions such as FITs.</p>
Policy support for renewables in phase 1 (pre- German 'take off')	<p>1974 – implementation of R and D programmes for Solar and wind.</p> <p>1978 - rapid increases in R and D spend on wind research and demonstration.</p> <p>1978 - German Solar Energy Industries Association set up</p> <p>1979 - Dedicated University research centres set up to explore renewable energy.</p> <p>1980 – Enquete commission, recommended efficiency and renewables as first priority but also the maintenance of the nuclear option.</p> <p>1981 - Federal Ministry of Research and Technology, 5 year study on renewables and energy efficiency.</p> <p>1988 –Wind and Solar targets set.</p> <p>1990- Feed-in-Law</p>	<p>1973 – CPRS Report on Energy Policy advising immediate support of a British wave energy programme.</p> <p>1974- formation of the Energy Technology Support Unit (ETSU)</p> <p>1975 - National Engineering Laboratory (NEL) positive report on prospects of Wind Energy</p> <p>1975 – Formation of Wave Energy Research Programme</p> <p>1976 – setting of ambitious targets for Wave power by Steering Committee (WESC) for targeted government support for R and D.</p> <p>1978 – Wind Energy Steering Committee (WISC) formed,</p> <p>1980s – ambitious targets set for Wind Energy by WISC.</p> <p>1990 – Non-fossil Fuels Obligation</p>
	Much civil society support and organisation for renewables; NGOs, Greenpeace, FoE, Institute	Broad coalition of support for renewables in civil society: FoE, Greenpeace, CPRE, popularity of

	of Ecology (Öko-Institut), Forderverein Solarenergie, Eurosolar	'soft energy path' and shift to renewables, largely generated by opposition to nuclear power in civil society (Wilson, 2012).
Resistance to renewables promotion	Government firmly committed to expansion of nuclear power in 1970s, limited renewables support; Substantial reduction in renewables R and D spend enacted by conservative government in 1982; Ministry of Economic Affairs offering minimal support for renewables; Ministry for Research prioritising nuclear R and D in the 1980s creating unfavourable conditions for renewables	Discontinuation of wave energy programme in 1982; CEEB prioritising promotion of nuclear; opposition from distribution networks towards wind energy; Decisions to reduce wind R and D in anticipation of privatisation; unrealistic targets set by DoE resulting in 'failed' demonstration projects;

Sources: (Jacobsson & Lauber, 2006; Lauber & Mez, 2004; Wilson, 2012)

In summary as backed up by the literature (Lipp, 2007; Mitchell, Bauknecht, & Connor, 2006; Wilson, 2012), there was considerable enthusiasm early on regarding renewable energy in both Germany and the UK. The UK's R and D funding related to wind energy in the 1980s actually increased whilst Germany's decreased. Both countries possessed strong advocacy coalitions and civil society support, and both faced significant political competition from vested interests – vested interests that, as can be seen from the other criteria, were arguably stronger in Germany than the UK, when the extent of industry related to nuclear power in considered.

5.4: Industrial strength – equipment supply industries

The tables below aim to give a general overview of differing aspects of the equipment supply industries of Germany and the UK with respect to renewable energy. Once more, it must be added that given space constraints this is by no means exhaustive, however aims to outline the general patterns.

Figure 28: overview of renewables capacity

	Germany	UK
Positioning in World ranking of top renewables producing countries (TWh)	4 th	18 th
Total renewable energy produced (TWh)	143.5 TWh	44.2 TWh
2014 renewables production figures (% total electricity production)	31% (Business Week, 2014)	14.5% (DUKES, 2014)
Total annual investment in renewables industry (£)	£24 Billion	£12 billion
Number of people employed in renewable industry	370,000	110,000

Figure 29: Wind Energy Industry

	Germany	UK
Global positioning in wind production (TWh) and ranking	46 TWh, 4 th biggest producer	19.6TWh, 9 th (including offshore)
Main Turbine parts Manufacturers	<i>Enercon, Nordex, REPower, Vensys, Siemens</i>	At present, the UK does not have British companies engaging in the manufacturing of main turbine parts (UK Gov, 2013)
Component Parts Manufacturers		GE Power, James Walker Tension Control Systems, 'Blade Materials' produced by BGB (slip rings) and Cooper and Turner (large slip rings), and Gear boxes produced by Dave Brown Gear Systems. Also 'developmental activities' including planning and consultancy work.
Contribution of onshore wind (£ GVA)	£ 150 million GVA	£ 548 million GVA

Figure 30: offshore wind industry

	Germany	UK
Global positioning in the production of offshore wind energy, cumulative installed capacity (MW)	520 MW	3681 MW
Ranking of equipment supply industry for offshore wind globally	5 th	1 st
Main Turbine Manufacturers	<i>Siemens, BARD, REpower</i>	There are currently no UK based Turbine manufacturers
Offshore wind development	<i>RWE, E.ON,</i>	<i>SSE Renewables</i>
Utility ownership of Offshore wind	<i>RWE, E.ON</i>	<i>Centrica, SSE Renewables</i>
Foundations, Component part manufacture		GE Power, James Walker Tension Control Systems, 'Blade Materials' produced by BGB (slip rings) and Cooper and Turner (large slip rings), and Gear boxes produced by Dave Brown Gear Systems. Also 'developmental activities' including planning and consultancy work.

Figure 31: Solar industry overview

	Germany	UK
Total capacity (MW)	26 380 MW	1188 MW
Ranking of solar market in Europe	2 nd	7 th
Industrial profile	There are 46 companies based in	There are currently no UK-based

	Germany manufacturing silicon, wafer, cell modules, 61 companies producing PV module materials, 53 producing PV system components, 94 producing PV equipment suppliers, 63 producing PV mounting tracking systems, and 73 specialist R and D institutions focussed on innovation in solar energy. World-leading companies include <i>Bosch, Solar Energy, Schott Solar, Conergy, SolarWorld, Sovello</i> . It must be noted that the German PV Industry is facing significant problems with many companies going out of business due to cheap solar production in China rendering much German manufacturing uncompetitive, as well as takeovers by Chinese companies.	manufacturers of solar modules, Substantial expertise has been built in the UK with installations and maintenance of solar panels including <i>Solar Century, Solar Tech, Big Green Company, A Shade Greener, Solus, Emotion Energy, South Downs Solar, Space Renewable Energy LTD</i> .
Jobs supported	87,500	15,620

Figure 32: Biomass industry

	Germany	UK
Installed capacity (GW)	11.5	4158
Ranking of biomass production in Europe	1 st	3 rd
Industry profile	Key players operating in German biomass include: <i>RWE Power, AE E Lentjes, GmbH, BMP Biomasse Projekt GmbH, Interargem, BPRE Biopower Renewable Energy, ENRO AG, PROKON Nord Energiesysteme, GEE Energy GmbH Co KG, and EnBW Energie Baden-Wurttemberg</i>	The UK's biomass market is largely dominated by <i>Drax Power Limited</i> , a UK company. <i>Wartsila Corporation, E.ON UK, Scottish and Southern Energy, EDF Energy, Energy Power Resources (EPR), Bronzoak Company, Purepower Holdings Limited, and Welsh Power Group Limited</i> .

6.0 relative scales of military-related nuclear activities and associated industrial interests

6.1 nuclear weapons capabilities

The difference between the UK and Germany regarding nuclear weaponry is stark. Germany has no operational warheads, the UK is estimated presently to have 225 (Norris and Kristensen, 2013). Although explorations were made in the 1950s for research programs these were abandoned, and Germany has produced no warheads, whereas the UK has produced at least 1,250 nuclear warheads between 1953-2003, with a peak arsenal of 500 between 1974-1981 (ibid). Over ensuing years the UK carried out a large number of tests of nuclear and thermonuclear weapons in locations including Australia, Christmas Island, and joint tests with the U.S.A in Nevada (Arnold, 2001), Germany carried out no tests. Britain also developed its own type of bomb, with much research effort going in to the development of There remains widespread support in the UK

Parliament for renewal or ‘modernisation’ of the Trident weapons system to continue the UK’s long term aim of ‘independent strategic deterrence’ (MoD, 2013). Germany has no such aims and is prohibited from doing so by international law.

6.2 Nuclear Ballistic Missile Infrastructure

Considerable infrastructure surrounds the nuclear missile capability of the UK. This includes AWE Aldermaston that is involved in the design, manufacture, and support of warheads. There is significant corporate interest in this area with the site being managed by Jacobs Engineering Group, Lockheed Martin UK, Serco, and with the UK Government maintaining a ‘golden share’ in all weapons facilities. There is also a site at Burghfield, and missiles are loaded on to submarines at HMNB Clyde near Glasgow. More than 4000 people are employed at Aldermaston, and more than 6,000 at Faslane (BBC News, 2014).

6.3 Nuclear propelled submarines

The UK has also had a long history of powering submarines using nuclear technology. Currently operable are four Vanguard Class nuclear powered ballistic missile submarines and six Trafalgar and Astute Class nuclear-powered attack submarines (Royal Navy, 2013). When the construction run is completed the Royal Navy will operate seven of the new Astute Class boats (ibid). All these vessels are powered by specialised PWR reactors constructed by Rolls-Royce (Watts, 2011). The UK continues to face significant challenges regarding the safe disposal of nuclear reactors of the 27 retired nuclear submarines. Nuclear warheads continue to be refurbished at the Atomic Weapons Establishment at Aldermaston, which also carries out substantial nuclear research (AWE Aldermaston, 2013). It is clear that there exists in the UK substantial expertise and capacity relating to specialised nuclear applications in weapons of mass destruction and their delivery systems. Germany has no nuclear-propelled submarines. What is more, submarines are considered to be a key industry and one of important scientific standing considering they are often thought of as ‘man’s most complex machine’ (Downing, 2014). Nuclear submarines form an important part of UK’s engineering expertise (H. Chalmers & Chalmers, n.d.).

6.4 Military-related equipment supply industries

The UK is a lead player in equipment supply industry for military related activity in the nuclear sector, related to nuclear-propelled submarines and missile systems. Rolls-Royce, a UK company, is a world-leader in designing, manufacturing, and operating various components related to nuclear-propelled submarines. This includes being the authority for the UK nuclear steam raising plant which is all a crucial element in all UK nuclear submarines (Rolls-Royce, 2014). In 2007 the MoD signed a landmark 10-year contract of up to £1 billion with Rolls-Royce to provide through-life support for the pressurized reactors on-board current submarines, and for the production of new components for the new SSN Astute Class and SSBN Vanguard Class submarines (Defence Industry Daily, 2007). Rolls-Royce also operate the on-land Vulcan testing facility (a submarine reactor based on land at Dounreay). In June 2012, the MoD signed a 1.1 billion contract with Rolls-Royce to sustain reactor core production at its Raynesway plant in Derby and refurbish the Raynesway site (Nuclear info, 2013). Rolls Royce has abandoned all other energy-related research and is concentrating investment in nuclear-related activity (Nuclear Energy Insider, 2014). Military-related engineering expertise thus forms a potentially important part of UK innovation strategy more broadly and can occupy important policy positions, for the chairman of the Engineering council is currently Rear Admiral Nigel Guild (Guild 2014 in Walport 2014) who was formerly controller of the Navy (Clements, 2006).

6.5 Stated future plans for military renewal

The UK has committed to the renewal of its nuclear missile Trident deterrent system (MoD, 2013) and has already signed contracts with American firm General dynamics worth £37 million (Edwards, 2014). The UK has

committed to a new fleet of nuclear submarines to replace the Vanguard class. Germany has no ambitions on either of these fronts.

7.0: Relevant characteristics of general national political institutions and elite cultures

7.1: centralised / decentralised political systems

The UK is a more centralised political system than Germany. The UK is a parliamentary democracy with the monarch as head of state. The UK utilises a 'first-past-the-post' electoral system, where a government is elected on a simple majority basis in elections that occur every five years. The first past the post elections take place in single-member constituencies, where the winning candidate becomes sole representative of the constituency in Parliament (Electoral reform, 2013). This UK system is – in international terms – unusually concentrated.

This contrasts strongly with the German system. Germany is a federal democracy divided into 16 regions or *Länder*. Thus there are Federal Laws applying to the whole of Germany, and laws that are only applicable to the land in question (Bundestag, 2013). Land laws cannot take precedence over Federal law, a factor that is enshrined in Article 31 of the *Basic Law* (ibid). Some laws cannot be made at the level of the *Länder*, such as all defence, foreign policy issues, currency and money, citizenship, the unity of the customs and trading area and cooperation between the Federation and the *Länder*. This difference between devolved and reserved matters is similar to those currently experienced in pre-referendum UK situation. As well as this, there are thirteen more *Länder* than the devolved nations of the UK, and thus the German system represents a more decentralised political framework, with profound implications for democratic engagement.

7.2: Prominence of Green Party

In Germany, due to the proportional representation system, Green Party to gain seats, and indeed they have been involved in mainstream German political life since the 1980's (Glaser, 2013). The Alliance 90/ The Greens Party (Bündis 90/ Die Grünen) formed through a merger between the Green Party of West Germany and Alliance 90 which formed during the uprising of 1989-1990. Before the two parties merged, The Green Party had several seats in the Bundestag, and with concern generated by the Chernobyl disaster, their anti-nuclear argument gained significant traction (Blowers and Lowry, 1998). The German Greens have served repeatedly in governments since 1998, when a key element of their agenda as part of the 'red/green coalition' with the SDP was to reach an agreement with energy companies and some SDP politicians regarding plans for the 'phase out' of nuclear power. This was agreed in 2000, and then implemented in the Atomic Energy Act 2002. The Greens were also part of a governing coalition between 2002-2005, continuing to oversee the first few years of the Renewables Energy Act 2001 (Metzger, 2013).

In the UK, whilst at the time of writing, membership of the UK Green Party is growing, they currently only have one MP, Caroline Lucas in Brighton Pavillion, compared to the Conservatives with 303, Labour with 257, and the Liberal Democrats with 56. All these parties are in favour of the construction of new nuclear power. As well as this, it was not until 2010 that a Green Party MP won a seat, displaying that their voice has been significantly more marginal in mainstream political debate than in Germany.

7.3: prominence of deliberative-style politics

To understand the patterns of German and UK political decision-making, it is important to look at the respective voting systems and how they influence this. In broad terms, the German system is an attempt to create a voting system between two – the British ‘winner-takes- all’ approach favoured by Anglo-Saxon countries, with a proportional representation systems that enables smaller parties to enter parliament (The Economist, 2013). In Germany two preferences are made on the ballot paper – one for a representative of a district of which there are 299 districts. The second vote is for choice of party, and if the party meets the 5% threshold then they occupy their share of second votes, or three directly elected members of parliament. This leads to far greater diversity of perspectives in German politics, and means that coalitions are a frequent occurrence. The ‘winner takes all’ and the first past the post system in the UK, ‘the Westminster model’ is articulated as an ‘adversarial’ system, where there are less ‘veto powers’ from critics of particular policies, whereas the German model is understood as a ‘consensual model’ where there are more veto powers for a wider distribution of critics (Strohmeier, 2008). Deliberative politics is considered more prevalent in Germany as a consequence across all sectors of society where ‘negotiation’ between different groups including businesses, trade unions, and various political parties to produce a shared vision, rather than majoritarian rule without the same levels of deliberation as in the UK (Lijphart, 2002). Despite Germany previously not having a decision-making structure on nuclear that NGOs felt adequately engaged in (Jahn, 1992; Kitschelt, 1986), German democracy has been ‘transformed’ through environmental issues (Dryzek, n.d.) and NGOs and critical voices were included in German decision-making measures, visible in the Ethics Commission report following Fukushima (Ethics Commission, 2011), a report commissioned by Greenpeace that was at the heart of decision-making. Despite ostensible engagement between Government and NGOs over nuclear issues in the UK, NGOs abandoned the nuclear consultations as they felt they were a ‘sham’, and following Fukushima for example, no direct participation or discussion of ethical issues involving NGOs was conducted as it was in Germany.

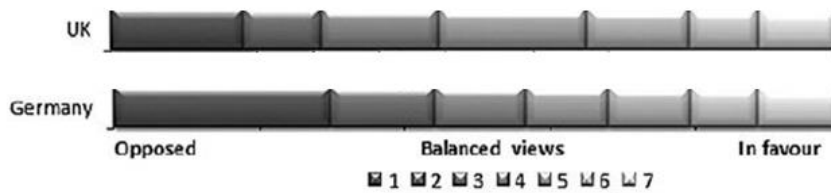
8.0: Broader Presence and activity levels of relevant social movements

Germany is generally regarded as having strong anti-nuclear sentiment (Winter, 2013), and this is often held up as being the main reason why the shift from nuclear has occurred (Johnson, 2011). It is important to establish more nuanced understandings of public opinions around nuclear power. The ‘public’ is not a static whole but rather the site of a variety of interests in numerous different aspects related to nuclear energy. As well as this it is crucial to establish the evolution of opinion given that again, a crucial consideration is public opinion during the formative period of the late 70s and 1980s preceding the policy starting point of the *Energiewende* in the late 1980s. The media is also an important consideration.

8.1: generalised public opinion on nuclear power

In general, polls conducted over the past few years have outlined greater public opposition to nuclear power in Germany than the UK (GlobalScan, 2011, Ipsos Mori, 2011; Globalscan, 2005). The polls conducted in 2011 occurred after Fukushima however, once government policy to phase out nuclear power was in place, considered to be a highly influential factor in determining opposition to nuclear (Globalscan, 2005). Going back to 2005, it can be seen that 22% of respondents in Germany agreed that nuclear power is relatively safe, and important source of electricity, and new plants should be built, compared with 33% in the UK (BBC News, 2011). In 2010 the NEA published an extensive report on public opinions on nuclear, charting opposition to nuclear power, as represented below:

Figure 33: Public strongly opposed to nuclear power ranked 1-7



Source: NEA (2010)

Another point addressed by the NEA report, is the change in public opinion generated by the climate change issue. In 2010 this displayed that the UK was only 6% points higher than Germany in terms of support for nuclear after an explanation regarding climate change mitigation potential:

Figure 34: Change in public opinion generated by climate change association

	Support for nuclear power (%) pre climate change mitigation explanation	Support in nuclear power (%) post-climate change mitigation explanation
Germany	22%	38%
UK	33%	44%

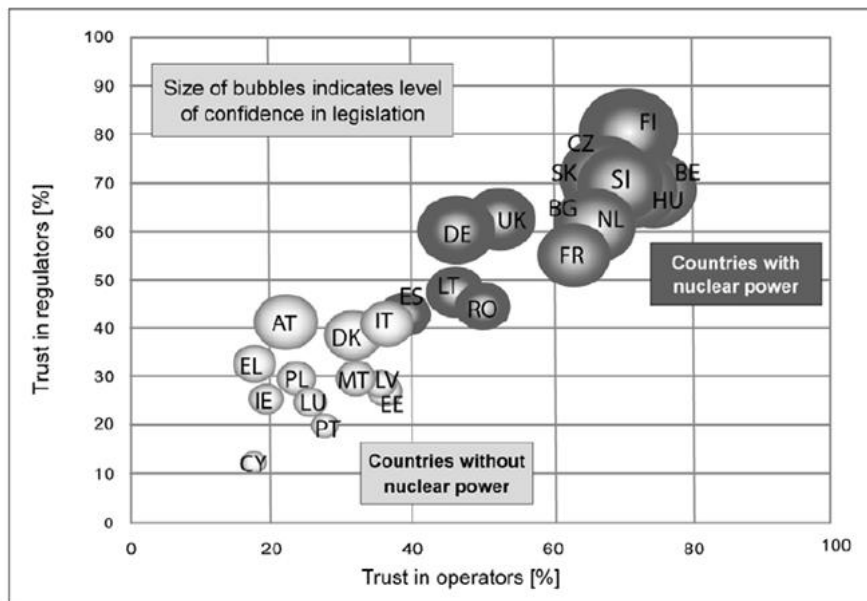
Source: NEA (2010)

An important consideration is also public opinion during the turbulent period of the 1980s preceding the identified policy-based starting points of the German energy transition. In both Germany and the UK, opinion polls though limited in number, showed general favour towards nuclear power (Van der Pligt, 1985). This began to change as the issue became more controversial in the late 1970s. Opinion polls conducted in 1982 demonstrated that 52% of respondents in Germany were in favour of new nuclear power with 46% opposed whilst polls in the UK indicated that only 34% of respondents were in favour with 53% opposed (Renn, 1990). A poll taken a few months after Chernobyl, 70% opposed nuclear power in Germany and 75% opposed nuclear power in the UK (ibid).

8.2: Baseline in public attitudes on nuclear: confidence in nuclear industry

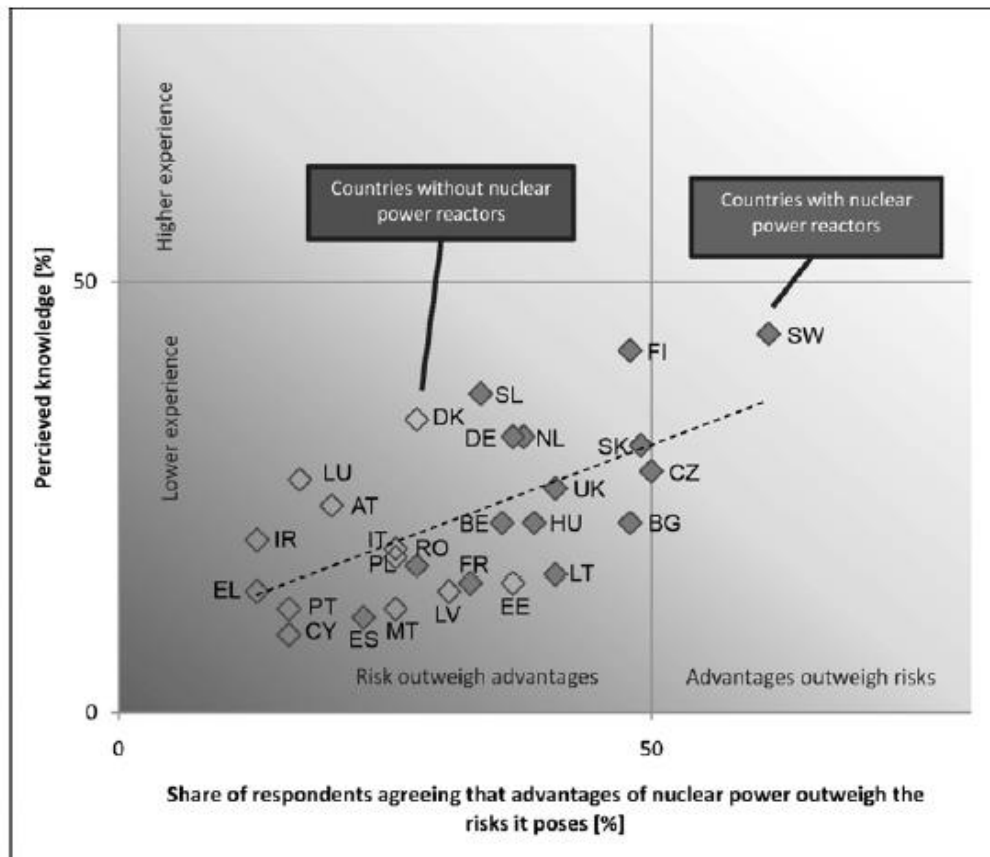
The figure below outlines differences between countries in terms of public confidence in nuclear regulators, operators, and legislators, with Germany and the UK in the middle identified as 'DE' and 'UK' respectively in 2010 before Fukushima:

Figure 35: Public confidence in nuclear regulators, operators, and legislators



What can be seen is that the UK demonstrates only marginally greater levels of public trust in nuclear regulators and operators than Germany. Confidence of legislation is indicated by the size of the bubble, and what can be seen is that there is a greater level of confidence in legislation in Germany, and Germany also appears to have greater levels of trust in legislation than France. Similarly in the 1980s following Chernobyl, Peters et al (1987 quoted in Renn, 1990), outlined that 60% of Germans surveyed found Federal Government and institutions surrounding nuclear power to be totally trustworthy.

8.3 Baseline in public attitudes on nuclear: perception of nuclear risk



Perceptions of risk and perceived levels of personal knowledge related to nuclear power also play an important role in forming overall opinions related to nuclear. As stated in the NEA report “...people who feel informed about nuclear safety tend to perceive less risk than those who feel uninformed” (NEA, 2010: 23). The claim that opposition to nuclear power is simply the result of a knowledge deficit continues to be repeated elsewhere (House of Commons Science and Technology Committee, 2012). Again the results in relation to Germany require further examination. Germany displays more perceived knowledge of nuclear power yet has a greater proportion of respondents who believe the risk outweighs the advantages than the UK, with lower levels of knowledge, yet a greater proportion who believe the advantages outweigh the risks. It is also worth pointing out that Germany has a greater proportion of respondents who believe that the advantages outweigh the risks than France, which despite having the electricity supply most dominated by nuclear power, has lower levels of knowledge perception and a greater proportion of respondents who believe the risks outweigh the advantages. Thus, no clear conclusions can be formed through risk perception as again the German picture complicates simplistic conclusions.

8.4 Maximal Scale of protests

Both the UK and Germany had rapid rises in opposition to nuclear power with the growth of the Green movement and NGOs in the 1970s. In terms of direct action protest both the UK and Germany had protest movements against nuclear power however the protests in Germany were more sustained and involved far greater numbers than the UK. In the UK these formed around the construction of Torness in the late 1970s which saw a series of protests involving 5 to 10 thousand people (Welsh, 2001). Such direct action protest died down in the 1980s as public inquiries became the favoured route of challenging nuclear power on the part of

NGOs (Wynne, 2010). In Germany the maximal scale of protests were greater and more confrontational. The protests against the construction of the Brokdorf reactor, 45 miles West of Hamburg, are widely identified as being particularly important point in the generation of the German anti-nuclear movement (Mecklin, 2013; Glaser, 2013; Rucht, 1990). There were also notable protests against the Kalkar Fast Breeder reactor, and in 1981 100,00 protested against the construction of the Wyhl nuclear power station (Mecklin, 2013). It must be noted that the protests did not transform into change of policy in the early 1980s. In fact, funding of renewables was cut and more favourable attitudes towards nuclear power became apparent in Government. Whilst UK protests faded, German protests continued against nuclear waste trains in the 1990s, however in 2011 the biggest protests since Torness took place against the construction of Hinkley C (BBC News, 2011).

8.5 intensity of public debate including media mentions

In the general political sphere an indication of the 'visibility' of debate around nuclear power can be seen from the way that policy actors regularly refer to a 'consensus' in favour of nuclear power (for example, Hutton quoted in Milne, 2011). Whilst clearly a political move to attempt to create certainty for new nuclear on the part of nuclear advocacy, such statements generally pass without controversy and it would be fair to say, would not be possible to make in Germany. The UK debate has been characterised as being dominated by a 'securitisation' discourse (Toke, 2013) where options for deliberation are limited by discussions of 'the lights going out' and threats of climate change. Certainly, the range of issues discussed in new consultation systems in the UK are less diverse than in the 1980s public inquiry system arguably representing a 'post-political' situation (Johnstone, 2014), where wide ranging debate is often limited by a singular focus on CO2 emissions alone 'trumping' other ethical considerations producing a 'reluctant acceptance' (Bickerstaff, Lorenzoni, Pidgeon, Poortinga, & Simmons, 2008; Corner et al., 2011) whereas clearly the issue remains politicised in Germany. Wittneben (2012) suggests that media reporting in Germany was more detailed and long-lasting in terms of coverage of the Fukushima disaster whereas in the UK attention was replaced on other issues, representing generally higher levels of reporting on nuclear issues in Germany than the UK.

9.0 Comparison of democratic quality

This section is utilised to place specific focus on studies that have been used to 'rank' and 'compare' qualities of democracy. This literature has not yet been used in transitions studies and

9.1 Majoritarian vs consensual democracies

Figure 36: Majoritarian (UK) and consensual (Germany) comparison

	Majoritarian	Consensual
Executive power	Concentration of executive power in single party	Power-sharing in coalitions
Executive-Legislative relationships	Executive is dominant	Executive-legislative balance
Party system	Two party system	Multi-party system
Voting system	Disproportionate representation	Proportional representation
Interest group systems	Pluralist interest groupings with 'free-for-all' competition	Coordinated and corporatist interest group systems aimed at compromise and

		concentration
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Source: Lijphart, (2012)

‘patterns’ of democracy (Lijphart, 2012; Lijphart, 2002). Lijphart’s work categorises a key difference between ‘majoritarian’ and ‘consensual’ democracies, which provides a useful distinction between Germany and the UK. The ‘Westminster model’ is used as the archtypical example of a majoritarian democracy in Lijphart’s categorisations whereas Germany is considered to be more of a consensual democracy in. Although of course there are many nuances in the on-going transformations in British and German political systems. Lijphart (2012: 7-8) conclusion is that “...consensus democracies scores significantly higher on a wide array of indicators of democratic quality and they also have better records with regards to governing effectiveness”.

9.2 Democracy Barometer democracy ranking

The Democracy Barometer project categorises and assesses democracies in 30 ‘established’ democracies judging each case in relation to 3 ‘principles’ and nine ‘functions’ including ‘freedom’ (individual liberties, rule of law, public sphere), ‘control’ (competition, mutual constraints, Governmental capability), and ‘equality’ (transparency, participation, representation) (Bühlmann, Merkel, Müller, & Weßels, 2011). Countries are ranked accordingly, and again provide a stark contrast between the UK and Germany where Germany is ranked 11th scoring 73.2 and the UK is ranked at number 26 with a score of 44.6 (Hall, 2011).

9.3 Economist intelligence Unit rating

The Economist Intelligence Unit has produced an important report on ranking democracies in its ‘Index of Democracy’ report 2010. The report assesses The index is based on five categories: electoral process and pluralism; civil liberties; the functioning of government; political participation; and political culture (Economist Intelligence unit, 2010). In this ranking system Germany is rated 14th and the UK 19th.

9.4 Global Democracy ranking

The Global Democracy Ranking is undertaken by the Democracy Ranking Association in Vienna. The quality of democracy is again based around several indicators covering aspects including gender balances, press freedom, corruption, political party change, change of head of government, civil liberties, political rights (see Campbell, 2008)for more details on methodology). In this rating system, Germany is ranked 8th and the UK is ranked 13th.

Figure 37: Summary table of democratic rankings

Rating system	German ranking	UK ranking
<i>Democracy Barometer</i>	11 th	26 th
<i>Economist Intelligence Unit 2010</i>	14 th	19 th
<i>Global Democracy ranking</i>	8 th	13 th

DISCUSSION OF FINDINGS

Summary of Key Patterns

Below is a table summarising how Germany and the UK compare under each of the nine criteria. A short text in each case indicates the broad picture that may be inferred from the discussion so far.

Criterion	1: General market conditions	2: Nuclear penetration in generating mix	3: strength of nuclear manufacturing industry	4: scale and costs of renewable resources	5: strength of industrial interests potentially relevant to renewables	6: scale of nuclear military activity	7: characteristics of political culture	8: activities wider of wider social movements	8: Comparison of 'democratic quality'
Germany	'Coordinated economy', more state intervention, higher public spending	Higher proportion of electricity generated 25%, greater total amount	Best performing industry in the world on many indicators, best load factor, economies of scale, industry world leaders all aspects of the supply chain, fairly high levels of R and D expenditure on nuclear power	Significantly lower and more expensive overall resource	Significant – industry leader, in wind. Troubled Solar industry. No offshore supply industry.	No military nuclear activity	Decentralised, proportional representation, strong green party, minority parties, 'consensus building', more deliberative	Strong anti-nuclear movements, 100,000 person protests - extensive public debate on nuclear,	'Consensual', consistently rated as more democratic than the UK in comparative measurements of democracy
UK	'market economy' neoliberalism, less public spending on R and D	Lower proportion of electricity generated by nuclear (19%) half as much power generated from nuclear as in Germany	Scores badly on most indicators, lower load factor, no industrial strength at many parts of the supply chain, low levels of R and D expenditure	40% wind potential of Europe, 50% wave and tidal potential of Europe, long coast, significant resources	Less industrial strength, no indigenous turbine manufacturers, significant offshore wind industry, but built by foreign companies. But strong offshore equipment	Nuclear deterrent. New fleet of nuclear-propelled submarines, Rolls Royce a	Centralised, 2 party system, absence of smaller parties, minimal green party involvement, adversarial, 'expert-driven' with respect to nuclear	Not large protest movement, NGO presence, often excluded from public debate? Public opinion ambivalent on nuclear	'Majoritarian', Rated lower than Germany in comparative measurements of democracy

					supply industry.				
Ceteris Paribus Proposition	Discontinuation of nuclear significantly less likely in Germany	Discontinuation of nuclear significantly less likely in Germany	Discontinuation of nuclear significantly less likely in Germany	Discontinuation of nuclear significantly less likely in Germany	Mixed picture. Discontinuation marginally more likely in Germany although historical context makes this criteria complicated	Mixed picture, given formal separation of civilian and military nuclear activity the extent to which military nuclear activity has a bearing on civilian nuclear power requires further research. . Discontinuation marginally more likely in Germany	Discontinuation more likely in Germany	Discontinuation more likely to occur in Germany	Discontinuation more likely to occur in Germany
Locus within or beyond the scope of conventional analysis of innovation dynamics in energy-related sectors or sociotechnical regimes	Within	Within	Within	Within	Within	beyond	beyond	beyond	beyond

Comparing Dynamics ‘Within’ and ‘Beyond’ Energy-Related Regimes

From the above summary table, a quite clear picture emerges of the comparative implications of the dynamics considered under different criteria for reasonable judgements over the relative likelihood of a discontinuation in nuclear incumbency in Germany as compared with the UK. All else being equal, it might be expected under criteria concerning: (i) general market conditions; (ii) nuclear penetration in the generating mix; (iii) the strength of domestic nuclear manufacturing industries; and (iv) the scale and costs of available renewable energy resources; that Germany would be a significantly less favourable environment than the UK, for the successful challenge of nuclear incumbency.

The picture is less clear under criterion (v), concerning strength of potential industrial interests in relation to renewables. Here, with interpretations depending on framing, a rigorous approach is to adopt a position of caution with respect to the hypothesis under scrutiny. The results may appear surprising given that the UK devoted more of its Energy R&D spend on wind energy than Germany throughout the 1980s, the period preceding Germany’s ‘take off’ from 1990 onwards. And the findings would also suggest that things are not as simple as German enthusiasm for renewables being the overriding factor. Under broader criteria concerning: (vi) the scale of nuclear military activities; (vii) characteristics of formally institutionalised political culture; (viii) activities of wider social movements, and (ix) assessments of democratic quality this reverse picture also seems more strong, again suggesting more likely conditions for nuclear discontinuation in Germany than in the UK.

So, with the current empirical political contrast being as striking as discussed earlier between the German phase-out of nuclear power and the prospective UK resurgence, the implications seem quite clear. On the basis of this evidence, those factors that appear to have been most relevant to the actual comparative course of events in these two countries are those that pertain not to the status or dynamics of the nuclear or energy industries themselves (the ‘focal regime configuration’), but to much wider and more general political factors. In other words, it is difficult to understand unfolding patterns of events on the basis either of the direct conditions in the incumbent nuclear regime, or of the circumstances of the most immediately challenging renewable niches (however these are construed). Indeed, in short, the key factor that seems most salient to the direction of the observed contrast, might better be summarised as the generally encompassing styles and conditions of democratic governance in these two countries, than as being directly to do with relative strengths or capacities in expertise, capabilities or resources among incumbents or challengers.

Crucially, the picture here is not one in which these broader political factors beyond the focal configuration of incumbent and challenging regimes, are concluded to play a *contributory* role to promoting discontinuity. Instead, it appears in this case, that it is wider political dynamics and circumstances beyond the context of energy as a whole, that have *overcome* conditions operating directly between incumbents and challengers, that would otherwise most likely favour continuity. This accords with other recent studies on similar issues, like Lockwood’s analysis of political factors bearing on energy policy in the UK and Germany (Lockwood, 2014), which suggest that wider political dynamics are not best approached as ‘additional factors’ to incumbent/challenger relations. Making a similar point, but with regard to ‘landscape’ dynamics, Kern and Mitchell (2010) highlight contrasting responses to more general ideological conditions like global neoliberalism. But the resulting processes across multiple discursive media and diverse contexts are (for reasons discussed earlier) poorly characterised in a threefold vertical ontology setting ‘the regime’ under an overarching landscape and above nested niches. In order to appreciate of the more intimate relational dynamics in particular contextual dynamics agency, it may be necessary to employ a more nuanced and variegated picture, free of set-piece categories. This will be returned to below.

For its part, the pattern under criterion (viii) means particular further attention is warranted with respect to the activities of social movements and public opinion. Here, an explanatory *casual* factor could simply relate to a particular ‘framing struggle’ or ‘size of protest movement’ or ‘presence of the Green Party’ in Germany than

the UK. Examples from other contexts point towards things not being so simple however. This factor of social movements and ‘framing struggles’ is well explored in wider literatures concerning conditions for destabilisation of sociotechnical regimes (F.W. Geels & Verhees, 2011; Penna & Geels, 2012; Turnheim & Geels, 2012). And in the above comparison of the cases of nuclear incumbency in the UK and Germany, this factor seems strongly in alignment with the observed trend. And of course, the role of anti-nuclear movements in driving Germany’s nuclear discontinuation is more widely commented on – acknowledging the large scale and high profile of the German protest culture that emerged in the 1970s and 1980s as contributing to a long-standing broader climate of concern over nuclear power (Rucht, 1990). As described in the above empirical discussion, Germany certainly had many extremely large and important protests involving hundreds of thousands of people. And – as compared here – the UK did over decades display markedly lower intensities of large scale direct action protest activity.

Indeed, one of the most common casually-attributed reasons for the distinctive German experience in this field, highlights the role of the German anti-nuclear movement as the overriding driver of Germany’s policy of nuclear phase out (Rucht, 1990). But this may be overly simplistic. Indeed, there arises a potentially significant qualifying point. Germany is not alone in experiencing very strong anti-nuclear mobilisation. For instance, protests involving hundreds of thousands of people also occurred against nuclear power in France (Kitschelt, 1986). Yet this is a country currently displaying the highest share in the world of nuclear power in its electricity generation and which maintains a strong commitment to a continued nuclear strategy. Equally, in Spain, arguably the largest anti-nuclear protest ever to have taken place, involved more than 200,000 people in 1977 (Rudig, 1990). But this was not at the time (or for many years afterwards) associated with any tangible concerted high-level move against the then-continuing incumbency of nuclear power (ibid). Looking further afield, large scale protests against the building of new power plants in Taiwan in 2013 have similarly failed to exert an effect comparable with that in Germany (Sun, 2013). Similarly, large and increasingly violent protests against nuclear power have also been ongoing for years in India, which also continues a nuclear strategy (Doherty, 2011).

So, national political propensities to very large direct action mobilisations – that reflect serious public concerns against nuclear power – are not restricted to Germany. Yet these developments elsewhere are not associated with the same kind of high-level political turnaround. In short, many countries experiencing the most intensive anti-nuclear mobilisations nonetheless persisted in adherence to incumbent nuclear trajectories. And this includes not only diverse contexts like Taiwan and India, whose standing as ‘democratic’ polities is broadly significant, but open to periodic question (Leib & He, 2006; Li, 1997; Sen, 2005). It also includes countries like France and Spain, with specific forms of liberal western European (supposedly) ‘democratic’ governance that are ostensibly quite similar to those practised in Germany and which are widely reckoned to provide for broadly similar degrees of responsiveness to citizen concerns.

With respect specifically to the UK, it is also important in this regard, that social movement activity is not the sole indicator of political pressure considered under criterion (viii). Perhaps even more important is the status of general public opinion. And in this respect, the apparently marked contrast between the UK and Germany with respect to protest intensity, is much less pronounced with regard to more general patterns in public support or scepticism over nuclear power. As also discussed under criterion (viii), the balance of public opinion over nuclear power in the UK and Germany is actually rather similar, when compared with the background patterns across European countries more widely. So, it appears that the power and intensity of anti-nuclear movements is not a factor that can fully explain on its own, the German contrast with the UK (Andy Stirling, 2014).

The long-time presence of the Green Party in German politics has also been quite persuasively noted as an important factor in determining the trajectory of nuclear policy compared to the UK (Wittneben, 2012). However, the presence of the Green Party in Germany cannot be divorced from conditions also bearing on the

discussion of 'qualities of democracy', hinging to the degree that it does on the difference between proportional and majoritarian voting systems, as well as centralised structures of government compared to decentralised ones. And Finland also provides an interesting counter-case for the concluding that prominent participation by Green Parties in political life is of itself an overriding factor, rather than being embedded in wider contextual aspects. Finland was the location where a Green Party was first part of a government in 1995 (Carter, 2007) and has been subsequently, yet Finland is one of the few countries in Europe that is still constructing new nuclear power (World Nuclear Association, 2014).

Again, what seems to be required in addition is broader attention not only to other structures and processes in wider governance, but to the various ways in which diverse institutions, procedures, discourses and interests are – in the most general of political senses – enabling or suppressive of the kind of democratic exercise of dissenting agency that seems so strongly implicated in the capacity to discontinue an entrenched techno-institutional system. In short, this study therefore raises a question as to whether one of the most crucial factors in the success or failure of incumbent-challenger dynamics in large scale sociotechnical transformation like the discontinuation of nuclear power, may actually lie to a neglected extent in the conditions bearing on the general status of 'democratic governance' in the widest of senses.

Implications of – and for – 'Democracy'

The ninth criterion applied here illuminates clear differences in the quite diversely construed 'qualities of democracy' displayed by Germany and the UK (Bühlmann, Merkel, Müller, et al., 2011; Campbell, 2008; A Lijphart, 2012; Arend Lijphart, 2002; Munk, 2012). What is especially compelling, is that the overall picture remains constant, despite the detailed contrasts in the characterising of what constitute qualities of democracy.

It was reviewed earlier how development of nuclear power has long been argued in various quarters to be associated with various 'democratic deficits' (Blowers & Pepper, 1987; Massey, 1988; Schrader-Frechette, 1980), a point that continues to be argued (Sovacool & Valentine, 2010, 2012). So, a speculative further scoping of the wider implications of the above findings, might undertake a similar correlative approach to give a provisional indication of relations for countries more widely between commitments to nuclear power and democratic rankings. By reference both to the Democracy Barometer project and the Economist Intelligence Index of Democracy, it is evident to a degree that measured 'levels' of democracy provide a rough indicator of nuclear commitment. Those European countries constructing new nuclear power do tend to lie lower in the various rankings. For example, in the Economist intelligence Unit rankings only the first 26 countries are considered to be 'full democracies', with those positioned between 27 and 79 in the rankings being classified as 'flawed democracies'. The complete list of European countries that are presently committed to nuclear new build occupy the following positions: Czech Republic – 16th ; UK – 19th; France – 31st; Slovakia – 38th; Hungary 43rd; and Bulgaria 51st (Economist Intelligence Unit, 2010). A similar picture is evident in the Democracy Barometer, where countries currently pursuing new nuclear build again feature near the bottom end of 30 'established' democracies: Czech Republic -21st; Great Britain – 26th; France – 27th; Poland – 28th; South Africa 29th.

However, it is important to acknowledge exceptions to this picture. Finland is also a country planning new nuclear build, yet lies relatively high in democratic rankings (7th on the Economist ranking, and 2nd on the Democracy Barometer). Although just one country among several others showing the reverse patten, this does put any simple interpretation into question, suggesting a more complicated picture and requiring attention to detail. But what does remain clear, is that wider patterns across larger numbers of countries than the two focused on in detail here, certainly do not refute the general salience of the hypothesis emerging from the present study: that qualities of democracy are more relevant than often conceded to nuclear discontinuity in

particular and (potentially) technological discontinuity in general. Whether this might be due to effects of democratic culture on forms taken by energy strategies, or by countervailing impacts of nuclear strategies on democracy itself, must remain moot – alongside many other such details. But there does seem sufficient evidence for a possible association, that further sociotechnical research might usefully focus more closely on this question. And this raises potentially important general issues for analysis of sociotechnical change, which this last section will explore.

Identifying a series of factors or forces that are said to contribute to shaping the direction of any large scale sociotechnical change necessarily de-contextualises the phenomena that are prioritised for attention. Notions of ‘democracy’ are no exception. And, of course, this is neither unusual, nor is it necessarily wrong in itself. The foregrounding of particular parameters necessarily backgrounds others and is an unavoidable aspect of any systematic comparative research. In the light of earlier conceptual discussion in this paper, the main risk about which to be most vigilant and prudent, is to avoid a situation in which categories are used in a circular fashion: both framing the analysis in advance and mediating the interpretation of results. Where this occurs, highlighted factors may be attributed undue causal roles in and off themselves, more on the grounds of their subjective visibility and facility in the analytical framework than from any objective salience. This may be a danger, for instance, with an ostensibly singular ‘level’ of analysis, like a regime, that is in fact radically ambiguous and multivalent and for which key relations are horizontal with parallel phenomena, rather than vertical to other ‘levels’.

As was discussed at the beginning of this paper, in such general ways, that apparently distinguishing features in case study research may often be at least as reflective of the conditions of a researching subject as of the researched object (Haraway, 2004). So particular care is necessary, with regard to whether relatively less visible but nonetheless highly relevant factors may have been missed. Fortunately, the form of the presently emerging hypothesis is itself a guard against the worst consequences of this syndrome. What is argued here, is that general qualities in wider political culture that are under-specified in prevailing theory, may assume greater importance in explaining the contrasting cases, than do some of the particular explicitly and categorically-identified dynamics around the focal regime configurations. It is not necessary to be precise as to the exact nature of these general qualities, in order for the point about relative emphasis to remain salient. The argument rests on the relatively inductive evidence gathered in relation to a wide range of examined parameters, rather than on relatively deductive application of a particular prior explanatory framework.

But it may be useful to discuss some of the more general issues that are raised by this emerging finding. Other approaches may be relevant. For instance, (not unrelated to understandings of diverse forms of democracy) a ‘varieties of capitalism’ approach may offer useful insights in understanding the different practices related to market intervention and market steering which are used to differentiate between ‘coordinated’ and ‘market’ economies of kinds held to be exemplified in Germany and the UK respectively. In their analysis of renewable energy financing policies, Toke & Lauber (2007) identify key differences between ‘Anglo-Saxon’ and ‘German’ responses to neoliberalism, and how these different contextual responses to neoliberal hegemony enable very different outcomes. Here, German Feed-in-Tariffs were more interventionist in terms of deliberately creating new markets for renewable technologies whereas the ‘Renewables Obligation’ of the UK approach was less interventionist in terms of leaving the market largely as it was and thereby aligning more with the general principles of neoliberalism as they are widely understood (Harvey, 2007). In reflecting capacities to assert deliberate collective agency in the face of overbearing global pressures, this contrast in itself raises an important aspect of what might be thought of as a significant ‘quality of democracy’.

On similar lines, recent work has focussed on the lack of attention in transitions literature towards these broader contextual conditions which extend beyond just a particular technological regime and can be seen in approaches using ‘policy paradigms’ as a focal point of analysis (Hall, 1993; Kern, Kuzemko, & Mitchell, 2014; Kern & Mitchell, 2010), as well as ‘policy mixes’ (Rogge & Reichardt, 2013). Relating paradigms to what they

hold to be the under-conceptualised 'landscape' level of the Multi-Level Perspective, Kern and Mitchell (2010: 14), discuss prior political commitments towards market liberalisation which runs *across* various regimes in the UK. They argue that "...political landscape factors constrain transition governance at the regime level". This again reflects a point made repeatedly in this paper concerning the sufficiency of a hierarchical ontology, for dynamics that are more horizontal and pervasive. Either way, Kern and Mitchell hold this to be a crucial factor slowing the UK's push towards similar market interventions to those achieved in Germany in order to promote a shift towards sustainability. Again, the conjunction of an attributed common aim, but a differential delivery holds implications for the relative strength of capabilities to enact democratic agency.

Also related to broader contextual dynamics, Kuzemko (2014) has drawn attention to processes of *politicisation* and *depoliticisation* within energy paradigms. This analysis outlines how the differing 'political capacities' of particular actors to enact more directed transitions to sustainability are potentially diminished by paradigmatic factors, in this case commitments to market liberalisation. Related to the idea of political capacities Lockwood (2013) discusses the importance of broader *political commitments* in enabling social-technical transitions, giving the example of the challenges of sustaining the *Climate Act 2008* and its potential instability due to political challenge. Again, a difference in capacities to undertake explicitly (and so accountably) political agendas in the face of default pressure towards otherwise relatively technical managerial compliance with incumbent global market pressures also relates to crucial qualities of democracy. In a discussion elsewhere of the comparative differences between renewable energy policies in Germany and the UK, Lockwood (2014) (like Toke and Lauber) again notes propensities in Germany for more direct intervention in markets as opposed to the less interventionist approach of Britain. The focus of these accounts on the broader contextual and institutional frameworks which enable or constrain certain policy decisions moves the debate forward considerably. Whilst regime theoretic approaches focusing on 'sustainable transitions' offer compelling accounts of the ways in which particular technologies evolve in a certain context, the question of *why* certain kinds of policies are arrived at in certain contexts and not others, as well as why certain policies are sustained in certain contexts and not others, is often insufficiently explored (ibid). Simple comparative questions of why certain decisions are 'possible' in one policy context and deemed 'impossible' in another - in this case, the possibility of a sustainability trajectory without nuclear power in Germany, and the 'impossibility' of achieving sustainability without nuclear power in the UK context, is left largely unexplored. This again relates to the foreclosure of the political in particular contexts (Johnstone, 2014; Swyngedouw, 2009; Žižek, 1999), where certain issues assume the status of 'scientific necessity' rather than political 'choices' open to deliberation. Again, where this happens, qualities of democracy might be thought correspondingly attenuated.

For his part, Lockwood (2014: 12) goes on to argue "the importance of context for policy feedback effects suggests that differences in speeds and paths of green transformation in different countries may be related to *institutional diversity* across countries". These influence what can be considered as the 'political opportunities' (Cowell & Owens, 2006; Kitschelt, 1986) available to particular actors, and the ways in which the legitimacy of certain discourses related to differing sustainable transitions become apparent. Whilst work on 'policy paradigms' and institutional variations has significantly advanced these discussions, they may still be loosely thought of as examining the conditions which enable or constrain particular decisions to be made or policies to be pursued. But at present, they maintain a fairly static picture in terms of examining the *agency* of different actors understood in the context of the distribution of power within differing institutional configurations. It therefore seems there is considerable further work to be done on distributional issues. Relating closely to the final criterion in the present analysis on 'qualities of democracy', general issues of equity are significantly under-explored in the general sustainable transitions literature. Distribution is an inherently 'horizontal' rather than 'vertical' concept of a kind that can easily get lost in an ontology of structured 'levels'. McCormack, for instance, shows how 'decisions' and 'policies' can be understood as distributed spatially and temporally (McCormack, 2011), with different actors enabled and constrained in various ways by 'horizontal' relations

across the interactions between discourse, actors and institutions, and the ways paradigms themselves are transformed.

Perhaps relevant here, is that Jhagroe & Loorbach (2014) in defending regime theory, nonetheless acknowledge the need for further research focussed on comparing different transition contexts related to matters pertaining to democracy. Likewise, associating this with 'landscape' processes, Hess & Mai (2014) argue for further investigation of 'varieties' of factors that determine political capacities to enact sustainable transitions going beyond the focus on 'regime'. Here again, they explicitly identify democracy as a key factor which correlates with greater levels of commitment towards policies designed to promote renewable energy. Such recent developments strongly chime with the present analysis. Perhaps more crucial to transformative change than structured 'vertical' interactions in an ontology of 'levels', are complex multidimensional and multivalent 'polythetic' relational distributions of power, implicating many kinds of agency on the part of diverse (often horizontally-interacting) actors. It is these forms of agonistic struggle, articulated in unruly ways in multiple specific contexts outside the generalised order of formally-recognised institutional levels, that remain significantly understudied in conventional transitions approaches. But it is with regard to these multifarious dynamics of power, that consideration of different 'qualities of democracy' that come to the fore in the present study, may be most relevant and operational to understanding of contexts for sociotechnical transformation and discontinuity. This also chimes with work elsewhere, like wider transformations in democracy itself, as the continuing co-constitution of 'emergent publics' (Barnett & Bridge, 2013; Marres, 2007) and technological evolution that challenge the conventional confines of representative democracy (Dewey, 1927) as well as many themes related to a perceived democratic crisis at present (Bühlmann et al., 2011; Crouch, 2004; Latour, 2007).

So, though it raises potentially profound issues for conventional theoretical approaches to sociotechnical change, the present case study seems in good company in these debates (Hendriks, 2009; Hess & Mai, 2014; Jhagroe & Loorbach, 2014; Shove & Walker, 2007). What seems to be needed, are alternative frameworks for understanding and action. These need not be seen as competing substitute theories, in a manner reminiscent of the totalising vertical processes highlighted in regime theory itself. Instead, they might be understood more horizontally, as diverse complementary contributions to understanding and action. The response need not be the building of a single increasingly elaborated, ostensibly objective, 'Cartesian' explanatory scheme, then – for instance structured such as apparently to include democracy itself within its specified mechanics. Such a totalising framework may be usefully provocative, and should not be dismissed. As identified at the beginning of this paper, such grand explanatory frameworks can be essential to discipline building and policy justification alike. But where they can become especially problematic, is where they serve as a suppressive force on the emergence of what may be incommensurable modes of heuristic understanding, rather than causal explanation.

To conclude this exploration of the possible conceptual implications of this analysis for understanding sociotechnical discontinuity, it might be useful to sketch some of key aspects of alternative – potentially complementary – approaches to understanding the possible roles of qualities of democracy. Perhaps the most fruitful way to approach this challenge is to focus at root on the many complex dimensions and modalities associated with diverse dynamics of power (Bourdieu, 1998; Gramsci, 1971; Luhmann, 1995; Lukes, 2005; Sen, 2000; Simon, 1991; Veneklasen & Miller, 2002). This may help sharpen analytical resolution – and avoid romanticism or special pleading concerning particular normative notions or claims around democracy. One such approach begins by characterising power itself as being about '*asymmetrically structured agency*' (Stirling, 2014). This is not an orderly Cartesian structure for building apparently complete and definitive objective explanatory frameworks, mapping coordinates from the notional "bird's eye view", "seeing like a state" in the fashion mentioned earlier in this paper (Scott, 1998). Instead, it offers a means to more plural and situated heuristic understandings, based on polar coordinates that are explicitly qualified by the subjective focus – a portable compass from an acknowledged "toad's eye view" (Giwali, 2010)

Depending on what broadly distinctive characters of wider power relations thereby come to light, then, what comes to the fore in seeking to understand any *specific* instance of sociotechnical discontinuation, are the irreducibly *general* dynamics displayed in encompassing political cultures at large. Relating to holistic properties bearing on political economy (Blyth, 2009), civic epistemology (Jasanoff, 2005) and varieties of capitalism (P. A. Hall & Siskice, 2001; Hancke, Rhodes, & Thatcher, 2007), a diversity of wider social norms, institutions and discourses constitute a variety of modalities for the concentration and dissipation of disparate flows and contours of social and material agency (Buss & Overton, 2002; Knappett & Malafouris, 2008). It is general distinctions between these overall patterns in the general fabrics of power relations associated with particular polities, which may from time to time form potential decisive factors in achieving particular large sociotechnical discontinuities. It is the resulting general question of democracy that might easily be missed by an overly specific focus on the specific conditions of incumbency and challenge themselves.

So, it is (ironically) in these broadest of senses situated on different meanings and contexts of power, that concepts of 'qualities of democracy' may be seen as most fruitful for operationalising in the specific analytic task faced here. In these terms, 'democracy' refers not to any formally structured constitutional or procedural end-state (Laclau, 1996), but to a general institutional and discursive capacity to sustain diverse, complex, distributed processes of ongoing *struggle* (Laclau & Mouffe, 2001; Marcuse, 1969; G. Smith, 2003). In short 'qualities of democracy' refer to the many kinds of ways in which an encompassing political environment may afford '*access by the least powerful, to the capacities for challenging power*' (Stirling, 2014). This may be as true of the power of an incumbent sociotechnical regime like nuclear power, as of any other particular political, economic or infrastructural instance of asymmetrically structured agency. Even though it may mean different particular things under differing perspectives, then, it is in this way that the apparently very general concept of 'democracy' may nonetheless be relevant in rigorously focused analysis of the present kind. And the concept is certainly relevant (as we shall see), when turning to the question of the kinds of normative recommendations that might be made.

What makes all this conceptual deliberation about democracy relevant to the present specific discussion, is that these irreducibly pervasive features of encompassing political structures and arenas, may tend to be somewhat neglected in much current literature bearing on the conditions for technological discontinuation. Here, analysis of various kinds tends to focus on developing specific reductive explanations, rather than general appreciative understandings (Flyvbjerg, 2001; Weber, 1978). Despite the presently necessarily coarse grain characterisation of the concept of 'democracy' in terms of general capacities for challenging power, the implications may therefore be especially potentially significant for prevailing interpretations of incumbent-challenger interactions.

Of course, as has been discussed, there does exist a considerable subset of literature acknowledging the general importance to large scale sociotechnical change of wider political and cultural dynamics (F. W. Geels, 2014; F.W. Geels & Verhees, 2011; Kern, Smith, Shaw, Raven, & Verhees, 2014; Meadowcroft, 2009; A. Smith, Kern, Raven, & Verhees, 2013; A. Smith & Stirling, 2010). And in other areas of literature, the issues raised here might be referred to as features of the overarching 'landscape', that helps to condition processes at the level of the regime (Rotmans, Kemp, & Asselt, 2001). As a portmanteau for a diverse collection of often-unspecified factors that extend beyond the structural confines of a regime, this is tautologously true. But divergent democratic qualities are rarely observed to constitute the formative distinctions between landscapes. And anyhow, the observation made here concerning the potential importance of democracy, goes beyond any landscape metaphor at all. It refers not to a remotely-overarching, expansively-aggregated and pervasively-distributed structural sphere subject mostly to long-run secular trends. Instead, experience of democracy as '*access by the least powerful, to the capacities for challenging power*' is (ideally), a readily-accessible and responsive locale for the direct exercise of various kinds of agency.

And whether conceived explicitly or implicitly as embodied in ‘landscapes’, there also emerges a further crucially distinct feature in the present analysis. In that part of the existing literature that takes account of broader social and political aspects, these are typically advocated in *addition* to more concentrated attention on the dynamics operating within and around the focal configuration of nested contiguous and overlapping sociotechnical regimes. It is rare to find an emphasis on such wider contextual factors *beyond* this focal configuration, as being unequivocally *more* important than the dynamics operating between the incumbent regime and the context of immediate challenge. And, of course, this observation is even more pertinent with regard to conventional transition management and innovation studies, in which the scope of explanatory and prescriptive frameworks typically extend only into processes bearing most directly on a focal regime or sector.

The potential significance of this discussion, then, does not lie in any claim that broadly framed, irreducibly holistic and normatively loaded concepts of democracy, may in all cases constitute important frameworks for understanding the dynamics around the challenging sociotechnical incumbency. The point is, that there exist pressures in existing academic literatures to tend to neglect the potential roles of these kinds of consideration. And the implications extend beyond simply acknowledging the potential *additional* significance of these broader factors, to dynamics at play within a sociotechnical regime and its immediate conditions of challenge. What may possibly be at stake here in particular cases, is an appreciation of the *dominant* considerations.

CONCLUSIONS

This paper has assessed the background to key recent developments in the challenging and assertion of nuclear incumbency in two countries where these dynamics are arguably most strikingly contrasting: the UK and Germany. It did this by means of nine criteria designed on the basis of various literatures to explore key relevant factors bearing on nuclear incumbency and challenge in these two countries. Despite the complexities, the analysis found a relatively clear picture. On the basis of five criteria concerning the dynamics within and around the nested and overlapping sociotechnical regime configurations relating directly to electricity production, it might be expected that Germany would be significantly less likely than the UK to discontinue nuclear power. Indeed, these criteria together predict the opposite of the observed pattern where it is actually in Germany that the challenge to nuclear incumbency has so far proven most successful.

It is the four criteria that address factors operating beyond focal regime configurations (involving either incumbents or challengers), that are most in alignment with the observed pattern of developments. Yet these factors typically remain most marginal to conventional analyses of dynamics in sociotechnical systems and sectoral patterns of innovation. In short, in these ‘conventional’ terms, the UK’s renewed enthusiasm for nuclear in comparison to Germany’s nuclear phase-out seems rather hard to understand.

Building on some wider emerging literatures on these issues, the paper argues that it is crucial to the understanding of sociotechnical discontinuity in this case, that attention be paid to the importance of some broader and more general features of political institutions and discourse. Public opinion in the two countries is not so different as to drive such starkly contrasting policy outcomes. Levels of activity among anti-nuclear movements seem to be a factor, but are also evidently not decisive in themselves. Military nuclear commitments may well be important, but remain entirely unacknowledged in published energy policy documentation, so such secrecy would raise important issues around democratic accountability. But it is the more general implications around this theme of ‘qualities of democracy’ that seem to be most aligned with the observed pattern.

Of all the detailed factors explored, it is those bearing on the complex and multidimensional issue of ‘qualities of democracy’, that seem most clearly to accord with a situation in which the country apparently withdrawing most readily from this incumbent electricity generating technology, is the one where it is arguably more

entrenched and successful and where alternative renewable resources are manifestly less attractive. Put simply, the question is raised as to whether the main reason for nuclear discontinuity occurring in Germany rather than in the UK, is that the latter affords less opportunity for democratic pressure and challenge.

This is important, because – despite exceptions – general questions of democracy tend to be somewhat sidelined in mainstream academic analysis in this field. And there also arise some potentially important practical political implications. A neglect of the general importance of pervasive qualities of ‘democracy’ may result in policy attention fixating unduly on potential roles for *particular* interventions addressing conditions *within* a specific regime and its contiguous sources of challenge. This may lead to an overly concentrated emphasis on relatively specific measures like sectoral missions, targeted instruments, regulatory reforms, operating standards, fiscal adjustments, higher education provision, training capacity, research strategies, protective niches and so on. Without detracting from the potential importance of these kinds of intervention in many settings, the present analysis underscores a serious question over their sufficiency. What may often be required as well – or even more – than such circumscribed instrumental functions of policy, are entirely more radical and transformative qualities in encompassing political environments.

The overall contribution of this study is to substantiate the question as to whether the successful challenge of sociotechnical incumbency may often be as much – even sometimes more – a matter of the general qualities of democracy, than of any characteristics or interventions in or around particular regime configurations.

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