

Exploring the re-emergence of industrial policy: insights from the energy transitions of Denmark, Germany and the UK

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Abstract

In this paper, we explore the role of industrial policy in the energy transitions of Denmark, Germany and the UK. Industrial policy has re-emerged as an area of policy discussion in recent years yet there is still a degree of ambiguity regarding the characteristics and role of industrial policy in different national contexts. Additionally, the role of industrial policy has played in the ongoing energy transitions of different countries remains under researched. We introduce a conceptual framework for understanding the relationship between industrial policy and the different energy policy trajectories taken in the three countries. We identify different characteristics of the energy transitions of Denmark, Germany and the UK using dimensions of disruption, before exploring what the role of industrial policy has been in facilitating changes in the energy system of the three countries and in what ways industrial policy has re-emerged in response to disruptive changes underway.

Key words: industrial policy; energy transition; disruption, energy system, UK, Denmark

1. Introduction

Industrial policy has been an increasingly discussed area in academic literatures and policy discussions in recent years. A number of authors have pointed variously towards a ‘re-emergence’ (Aiginger, 2007) ‘return’ (Wade 2012), ‘renaissance’ (Ciuriak, 2011) ‘rejuvenation’ (Stiglitz, Yifu, & Monga, 2013), ‘reinvention’ (Lall, 2003), ‘resurrection’ (OECD Observer, 2012), and ‘resurgence’ (Ciuriak & Curtis, 2013; Warwick, 2013). Soete has defined industrial policy as *“structural policies designed to strengthen the efficiency, scale and international competitiveness of domestic industrial sectors, typically containing an element of national champions, of self-reliance in bringing about growth and development”* (Soete, 2007: 273). It has some overlap with innovation policy, through search for sources of competitiveness. Yet, it can also undermine innovation policy, when extensively focused on supporting existing industrial processes. It has historically been disconnected from environmental sustainability objectives, until the emergence of the notion ‘green industrial policy’ (Hallegatte & Vogtschilb, 2013). This notion has limited grounding in the traditional industrial policy literature (Pegels, 2014).

Green industrial policy, broadly defined as “government intervention to hasten the restructuring of the economy towards environmental sustainability” (Pegels & Lütkenhorst, 2014) is a relatively recent consideration for sustainability transitions literatures (P. Johnstone & Newell, 2017) however there are implicit cross-overs. Because a key aspect of green industrial policy involves shifting economic trajectories away from traditional industries towards new technological pathways such as renewable energy technologies (Schwarzer, 2013), and in sustainability transitions, a key focus is on how through the nurturing and empowerment of niche technologies and innovations, unsustainable socio-technical regimes become destabilised (Geels, 2002; Kemp, Schot, & Hoogma, 1998). Yet, there has been limited engagement with industrial policy literatures within sustainability transitions research, and it remains unclear the extent to which industrial policies and green industrial policies have played a role in sustainability transitions.

In this article we examine the characteristics of industrial policy in the energy transitions of Denmark, Germany and the UK and then explore the role that industrial policy has played in these energy transitions, and how issues arising from these energy transitions may have also played a role in the ‘re-emergence’ of industrial policy in the European context. Building on recent debates on the relation between sustainability transitions and theories of ‘disruption’ in energy transitions (Geels, 2017a; McDowall, 2017; Wilson, 2017) We build on a novel framework developed elsewhere (Johnstone et al, forthcoming), to efficiently compare and contrast the energy transitions of different countries based around dimensions of disruption.

Section 2 discusses the conceptual background, focussed on industrial policy and green industrial policy literatures as well as discussing debates around sustainability transitions and disruption, as well as discussing our analytical framework based on these literatures. Section 3 discusses the research method, while section 4 outlines our findings based on interviews with key stakeholders in the energy domain and a literature review. Section 6 discusses these findings based on six propositions regarding the role of industrial policy in sustainability transitions and the role that emerging transitions have played in the re-emergence of industrial policy. An industrial policy lens highlights important additional factors worthy of consideration beyond the usual focus of sustainability transitions and has important implications for research and policy regarding discussions around accelerating transitions.

2. Conceptual background

2.1 Industrial policy

2.1.1 Traditional industrial policy and its rejuvenation

Industrial policy is a broad term capturing different manifestations and forms of policy intervention (Dhéret et al 2014; Stolingen, 1996). At its broadest, industrial policy has been defined as “...a variety of public actions aimed at guiding and controlling the structural transformation process of an economy” (Bianchi & Labory, 2006: 3). More specifically, industrial policy is used in reference to “policies by which governments attempt to shape the sectoral allocation of the economy” (Greenwald & Stiglitz, 2013: 43). Industrial policy can be explicit or implicit, intentional or unintentional, but in effect it has typically meant that certain industries are favoured more than others, thus, shaping the sectoral allocation of the economy (Stiglitz et al., 2013). Most countries pursue an industrial policy through “any government decision, regulation or law that encourages ongoing activity or investment in an industry” (Yifu Lin & Monga, 2013: 23). In practice, this is likely to require elements of different policy fields, such as educational, innovation, economic and financial policies, so that new industries can reach what Yifu Lin and Monga describe as “economies of scale and become lowest cost producers” (Yifu Lin & Monga, 2013: 25).

Yet, the term industrial policy is a controversial one (Wade, 2012), stemming partly from fuzzy definitions, varying scope, normative questions, and differing applications between countries (Yifu Lin & Monga, 2013; Bianchi & Labory, 2006b). Thus, we argue that industrial policy cannot be easily discerned through a simple identification of stated industrial policy, but must be looked at in terms of identifying those policies, or mix of policies, which may be of relevance to the aim(s) of industrial policy. As such industrial policy lends itself to be systematised through the lens of policy mixes (Rogge and Reichardt, 2016), with instrument mixes including both ‘vertical’ sectoral interventions and ‘horizontal’ ones overlapping different sectoral domains and a broader range of actors. In addition, when it comes to ‘mission oriented’ industrial policy strategies (Mazzucato, 2013; Mazzucato, 2015; Mazzucato et al., 2015) long term ‘guiding visions’ around shared goals and challenges are another crucial component in coordinating industrial transformation.

Many facets of industrial policy are inspired by insights from innovation systems approaches (Malerba, 2002). For example, many accounts of industrial policy pinpoint innovation policy and long term strategic R&D support as key components of industrial policy (Andreoni, 2017; European Parliament, 2016; O’Sullivan, Andreoni, López-Gómez, & Gregory, 2013; Schwarzer, 2013). Other examples concern the importance assigned to industrial clusters (Karl & Möller, 2003), collaborative links with research institutions and industry (Hancké & Coulter, 2013), and coordination of industrial relations by government (Kalman & Tiits, 2014). These are all factors that are recognised as important in national innovation systems perspectives (Freeman, 1987), which explains overlaps in industrial and innovation policy.

However, national approaches towards industrial policy vary greatly. As Andreoni (2017: 246) states “The variation in countries’ industrial policy experiences is driven by their contextual—institutional and structural—and political economy differences as well as by the different policy space and rationales for government action.” Thus, the ways in which industrial policy can be compared includes differences in regional and national industrial policy, the role and type of finance (for example the presence of local and national banks), education and skills training policies, export oriented policies in relation to the state supporting industrial platforms and trade missions, innovation policy such as public R&D support, and the role of trade unions in decision making. That

is, comparing industrial policies involves examining factors that relate to institutional understandings of ‘varieties of capitalism’ (Ćetković & Buzogány, 2015; Hall & Gingerich, 2009).

The degree to which industrial policy has been used explicitly by policy makers over time is influenced by the broader economic context. Arguably, industrial policy had somewhat fallen out of favour from the 1980s onwards with the rise of ‘neoliberalism’ as a dominant form of economic ideology, with industrial policy being seen as a part of ‘inefficient’ government practices of ‘picking winners’. This gave way to privatisation and deregulation policies leading to increased governance through market mechanisms with an idealist minimal role for the State. However, in the wake of the financial crisis of 2008, a number of authors have pointed towards a ‘return’ (Wade 2012), ‘renaissance’ (Ciuriak, 2011) ‘rejuvenation’ (Stiglitz et al., 2013), ‘reinvention’ (Lall, 2003), ‘resurrection’ (OECD Observer, 2012), and ‘resurgence’ (Ciuriak & Curtis, 2013; Warwick, 2013) in industrial policy in recent years.

Much of this renewed interest in industrial policy stemmed from the response to the ‘Washington Consensus’ encouraging developing countries to take a more proactive governmental role in stimulating industry rather than relying on free markets (Harrison & Rodríguez-Clare, 2009). The renewed interest in industrial policy is driven by two main factors: first, the need to re-stimulate growth and employment in response to the economic crisis, concerns over structural imbalances in the economy, the prevalence of market failures, the political economy of market bail-outs, and the success of the emerging market economies (Warwick, 2013). Second, the pursuit of a number of societal objectives (Stiglitz et al., 2013), such as moving towards low-carbon and resource efficient societies. Modern industrial policy has been argued to include objectives related to the creation of a learning economy, addressing distributional issues and promoting employment (Stiglitz et al., 2013). For example, the European Union industrial policy is being reconsidered in response to unemployment and the decline of manufacturing (European Parliament, 2016), where the aim is to use industrial policy measures to boost the competitiveness of the EU region (Kalman & Tiits, 2014). Increasingly, also the challenge of climate change and the opportunities of bolstering employment and manufacturing around low-carbon innovation is being recognised (Spencer et al., 2016), paving the way for green industrial policy.

2.1.2 Green industrial policy

In recent years, discussions around ‘green industrial policy’ have become more prolific (Böhringer, Rivers, Rutherford, & Wigle, 2012; Cato et al 2013; Hallegatte & Vogt-schilb, 2013; Lockwood, 2016; McDowall & Ekins, 2014; Rodrik, 2014; Schwarzer, 2013). The idea is to ‘kill two birds’ by promoting more eco-efficient technologies dealing with an environmental problem while simultaneously bolstering economic competitiveness in order to deal with economic problems associated with industrial decline (Creutzig et al., 2014). Green industrial policy seeks to build new industrial trajectories around the green economy and, thus, explicitly addresses environmental policy objectives. There is recognition that green industries are often ‘infant industries’, and since ‘environmental externalities’ are not priced correctly (Lockwood, 2016), strategic and coordinated industrial policy that supports green technologies and mitigates and manages labour market processes is crucial (Lütkenhorst, Altenburg, Pegels, & Vidican, 2014). For example, as sustainability transitions gain momentum industrial policy can help prepare for new kinds of jobs and skills that become necessary following the closure of incumbent industries.

Pegels and Lütkenhorst (2014b) define green industrial policy as “government intervention to hasten the restructuring of the economy towards environmental sustainability” and outline five factors of

importance: inducing innovation, creating jobs, mitigating climate change, and minimising cost to consumers. As pointed out by Pegels and Lütkenhorst, international trade is a key consideration, with tariff protection, favourable customs and excise taxes, and ‘local content requirements’ representing potential instruments for protecting domestic manufacturing and fostering internationally competitive industries. Many different policy instruments have been identified as green industrial policy. For example, Schwarzer (2013) differentiates between regulatory and control mechanisms, environmental taxes, industry protection, and industry support mechanisms. This example illustrates that industrial policy not only overlaps with innovation policy, but in the context of sustainability transitions it also overlaps with environmental policy.

While policy and policy mixes are acknowledged to play a key role for governing sustainability transitions (Rogge and Reichardt, 2016), industrial policy is seldom explicitly mentioned and if so often only in passing. Also, the role of the state has not been a focal point of enquiry in the transitions literature (Meadowcroft, 2005), despite ‘niches’ implicitly relying on long-term state support as part of shielding, nurturing and empowering processes (Smith & Raven, 2012). More recently, however, through attention towards both ‘creative’ and ‘destructive’ instruments in policy mixes (Kivimaa & Kern, 2016a), as well as the ‘destabilisation’ of incumbent industries (Turnheim & Geels, 2012), attention towards more structural and directed processes of industrial change benefit of industrial policy are gradually emerging in the sustainability transitions literature. An example in this regard is the deliberate ‘phasing out’ or discontinuation of unsustainable technological trajectories (Stegmaier, Kuhlmann, & Visser, 2014).

2.2 Disruptive innovation in sustainability transitions

Sustainability transitions focusses on how transitions to low carbon futures can be understood and initiated through the support and nurturing of new low carbon niches and the destabilisation of existing unsustainable regimes be those in food, energy, transport, or water supply (Geels, 2002; Markard, Raven, & Truffer, 2012). Energy transitions has been a key focus in this area and recently a key discussion has focussed on the usefulness of ‘disruptive innovation’ or ‘disruption’ for understanding energy transitions (Geels, 2017; Johnstone & Kivimaa, 2017; McDowall, 2017; Wilson & Tyfield, 2017). It is argued by some that analysis of disruptive innovation following Christensen (Christensen & Rosenbloom, 1995) is too firm focussed and lacks a systemic understanding of the way in which regulation and institutions influence the shaping of markets and technological trajectories (Geels, 2017b).

However, as we argue elsewhere (Johnstone forthcoming), as opposed to the complexity often associated with accounts of socio-technical transitions, key dimensions of disruption in combination with socio-technical perspectives can provide a useful means of getting a quick overview and snapshot of the particular ways in which an energy system has transformed over time. As discussed in Johnstone et al, (forthcoming) this includes a focus on technological (Bower & Christensen, 1996), ownership and actors (Nagy, Schuessler, & Dubinsky, 2015), market and business model (Dijk, Wells, & Kemp, 2016; Richter, 2013) and regulatory disruption (OECD, 2015). We use the dimensions of disruption approach as a means of assessing the different ways in which the energy systems of Denmark, Germany and the UK have changed in order to understand the role that industrial policy had in these changes and how these changes have in turn shaped industrial policy.

2.3 Analytical framework

Building on the literatures discussed above, particularly in the ‘variety of industrial policies’ approach (Yin, 2003) we identify several factors that can assist in identifying and analysing industrial policy in each case study country. First, we include *traditional industrial policy* in the form of state interventions to support the competitiveness and industrial base of existing industries in a particular national context, and this reflects on the longer-term approach to industrial policy present in each country (Thompson, 2015), beyond simply the energy sector. Second, alongside this, evidence of *green industrial policy* in the form of support for the creation of new industrial trajectories around sustainable energy will be examined (Lütkenhorst et al., 2014; Pegels & Lütkenhorst, 2014; Schwarzer, 2013). Third, we look at industrial policy *instruments*. Industrial policies can take the form of differing instruments from vertical interventions for particular sectors or technologies such as direct subsidies policies, to horizontal policies such as establishing multi-actor trade platforms around industrial growth, as well as different scales of policy interventions on industry between national and regional (Aiginger & Sieber, 2006; Andreoni, 2017; Karl & Möller, 2003). Fourth, policies aimed at stimulating a country’s *manufacturing* sector also were identified above as being a key dimension of how industrial policies can vary (Hancké & Coulter, 2013; O’Sullivan et al., 2013). The fifth and final dimension we include is *consideration of skills, jobs and trade unions*, encapsulating a focus on the ways in which industrial policy can differ based on actions taken to support and prioritise workforce issues and jobs and the differing ways in which trade unions are involved in decision making (Aiginger & Sieber, 2006; Andreoni, 2017; TUC, 2016) .

Our analytical framework, firstly seeks to highlight the different characteristics of industrial policy in the three case study countries (RQ1). Then the framework captures the interplay between industrial policy and system disruption to answer our second research question. On the one hand, it addresses how industrial policy operates in an *enabling* or *hindering* manner to disruption in the energy system (as indicated by RQ2a), and on the other hand how disruptive innovation in turn shapes industrial policy (as indicated by RQ2b).

***insert figure of framework here.**

RQ1: What are the characteristics of industrial policy in Denmark, Germany, and the UK?

RQ2a: what is the role of industrial policy in enabling or hindering disruptive energy transitions?

RQ2b: how has disruption in energy transitions influenced industrial policy?

3. Research method

A country case study approach (Balch, 2015;) was adopted to understand the interplay between industrial policy and disruptive innovation in energy transitions.

3.1 Data Collection

We rely on in-depth interviews as a primary data source backed up by academic literature and policy documentation as secondary data sources. Regarding the former, expert interviews were conducted in the UK and Denmark during November 2016 – March 2017, comprising 13 interviews in the UK and 20 interviews in Denmark. Two members of the research team conducted interviews, one overseeing Denmark and the other, the UK. Interviewees were selected to represent expertise on

disruptive innovation in the energy sector and covered experts from different actor groups, including civil service, politics, utilities, industry associations and trade unions, non-governmental organisations and think tanks, consultants, and researchers. The interview duration ranged between 45- 95 minutes. The table below outlines how many interviewees were in each category in each case study.

Table 1: Number of interviewees per category in Denmark, Germany, and UK

Interview category	Number of interviews DK	Number of Interviews DE	Number of interview UK
Research	4	5	1
Utility	2	1	1
Ministry/ Politician	4	3	4
Think tank/ NGO	4	1	2
Industry Association	3	4	4
Trade Union	1	1	1
Total number of interviews	21	15	13

Source: Own.

Data collection was guided by a semi-structured interview guide, which was oriented around an open-ended questioning regarding industrial policy in order to understand how industrial policy are understood by actors operating within the energy systems of Denmark, Germany and the UK. As a consequence, interviewees were asked about their understanding of what industrial policy was and what its role in disruption was thought to be. Open-ended questions were followed up by prompts arising from the analytical framework.

Regarding the documentary analysis, for each case study country we conducted a literature review based around the key words of industrial policy, disruption, and energy transition. For each case study country, this resulted in a list of over 30 peer-reviewed articles and reports focussed on these three key areas, building important background contextual information regarding each case study country, as well as enabling triangulation of emerging research findings.

3.2 Data analysis

For the analysis of our primary data, we transcribed all interview manuscripts and then followed four main analytical steps. In a first step, the interview data was coded. For this, we developed an initial coding framework based on the analytical framework but refined it on the basis of the interviews. This refinement was accomplished by four researchers coding one interview individually, followed by a joint discussion to compare coding. This resulted in some alterations to the list of codes and the improvement of the uniform interpretation of codes. To enhance the reliability of our analysis we conducted two further rounds of comparative coding until a satisfactory level of mutual understanding of the codes and the coding procedure was achieved and a final list of codes was agreed upon (see Annex 1). Based on this, subsequently the first author coded all transcribed interviews in NVivo.

In the second step, we analysed the coded interviews. Following an initial coding and preliminary analysis of the interviews in NVivo, the most frequently used codes were selected for more systematic analysis. For this, we used an Excel spreadsheet as an assisting tool to generate an

overview of the main insight, using one sheet per country. In a first instance, the first author summarized for each country and each interview the key insights regarding the selected codes. Subsequently, these summaries were discussed with the co-authors, and in particular with those who interviewed the relevant experts, and modified, if deemed necessary. Based on these, for each country we then generated a joint interpretation of overall findings, arriving at one summary finding per code and per country. To do so, three authors first recorded their own interpretation of each code, which allowed for discussing differing interpretations and meanings. This analytical process facilitated the generation of consensus on meanings and of the results obtained. This joint interpretation approach was carried out for both cases to ensure robustness of the analysis. In a final analytical step we then, again for each country separately, focused on deriving the bigger picture and identifying overarching findings regarding our research questions.

In a third step, we complemented our interview findings with the empirical literature pertaining to the country cases. Apart from providing crucial background information related to the energy transitions and industrial policy in Denmark, Germany and the UK, this empirical literature was used to triangulate the interview data. Also, key statistics related to energy production, industrial and economic information, and R&D statistics were drawn from the literature to supplement interview insights. In a final step, country findings were compared with those for other countries and broader comparative themes were drawn out.

4. Findings

In this section, we present the results from interviews and secondary literature regarding the status of energy disruption and industrial policy in Denmark, Germany and the UK. In a related publication (Johnstone forthcoming) we have discussed disruption in more detail. We briefly summarise the characteristics of disruption in each country in the tables below, before going on to looking at characteristics of disruption which are briefly discussed, given that we have not done so in another publication. We then focus in more detail on what the role of industrial policy and different characteristics of industrial policy has been in the different status of disruption that is present in the energy sector of each country.

4.2 Disruptive innovation in energy systems

We set out in the tables below the characteristics of disruption in each country based on the five dimensions discussed in the analytical section as background to understanding the changes that have taken place in the energy systems of the three countries over the past three decades based on dimensions of disruption. Below these tables we give a brief overview of the key differences in the characteristics and status of disruption between the three countries. These findings are documented in a detailed manner in Johnstone et al (forthcoming).

TABLE OF DISRUPTION GOES HERE.

Source: adapted from Johnstone et al forthcoming

4.3 Characteristics of Industrial Policy

Before looking at the interplay between disruption and industrial policy we now look at the characteristics of industrial policy in each country based on interview material from experts in the field. What follows are three tables outlining characteristics of industrial policy in each country followed by a discussion of these findings below the tables.

Figure 1: characteristics of industrial policy in Denmark

	Point	Illustrative quote	Number of interviews
Traditional	Industrial policy was not explicitly discussed by interviewees.		
Green	Strong role of state in making industry investment in green change, from biomass, traditional industry investing in wind, and offshore wind industry combined with early recognition of climate challenge.	<p>"there was a political remit [from the early 1980s] where power companies were obliged to build a certain number of megawatts of wind" (DK7).</p> <p>"close collaboration between government and the [offshore wind] industry (DE5)</p>	13
Instruments	Vertical – long term subsidy manufacturers for turbine manufacture and electricity production.	"tax relief schemes for wind turbine manufacturers" (DE8	3
Manufacturing and supply chain	Skills diversification and retraining for green jobs	<p>"So maybe we could hand them over to somebody who needs them, so we made an announcement: 'We have 150 bright engineers, the best in the world on coal-fired plants. Does anybody want to take them over, not one by one but as a group; over all 150 people in one shot?' (DK1)</p> <p>"The wind. It's our new shipyard." (DK3)</p>	
Skills, jobs and trade union movement	the importance of the jobs creation in the overall Danish transition including convincing trade union actors in the 1980s.	"I think a good thing here about the green agenda is we convinced a lot of people in the unions back in the '90s that green was not...disrupting the jobs, because you can create jobs. It's a more broad discussion, but I think we have had this discussion at least since the '80s. It's also circular economy and all these things. It is a job creator." (DK8)	6
Innovation policy	The importance of long term Government test stations and R&D for wind turbine technology	"Some new technologies have been assisted through R&D. There is for instance we have built some test stations...These test stations are quite important for the manufacturers because if they have a new concept in the pipeline they can go there and test it and correct there also and so on" (DK9)	4

Figure 2 characteristics of industrial policy in Germany

	Key Point	Illustrative quote	Number of interviews
Traditional	Industrial policy not an explicitly recognised policy area in Germany due to controversy surrounding the term.	"...in Germany the debate was also a little bit not so outspoken about industrial policy because it is still a controversial paradigm. Not controversial in doing so, but controversial in naming it" (DE11)	3
	Industrial policy aimed at protecting existing industries	"The reactive element of industrial policy is more or less to prevent Energiewende policy from leading to a wave of relocations in energy-intensive industries" (DE5)	11
Green	The Energiewende as encapsulating green industrial policy	"a very central one..." "deliberately build up an industry" (DE3).	3
	The Energiewende not encapsulating green industrial policy	"the EEG has industrial policy effects, but is not really an industrial policy instrument, but an energy-economical instrument." (DE15).	3
Instruments	Coordination measures – platforms.	"in general this [industrial policy] is quite well coordinated between the ministries, I mean in the departments. Especially for electro mobility there is therefore a platform where industry and science are involved as well" (DE12).	2
	Export promotion	"the 'Export Initiative Energy' somehow merged with 'Mittelstand Global'... They are very bustling, do a lot of information tours, consult a lot of experts... There are lots of activities, lots of consultants are paid for it." (DE8)	2
	Lack of coordination of export promotion	"the Federation of German Industry (BDI) is always complaining that there are too many different public bodies or agencies trying to promote exports and that it's not well enough coordinated" (DE5)	1
Skills, jobs and trade union movement	Unions playing a progressive role in energy transformation	"the IG Metall is a very progressive union which has realised the opportunities coming from the disruptive transformation of the energy system" (DE7)	3
	Unions blocking energy transitions	"Right now, both the unions and politicians are blocking everything related to, say, lignite, out of fear for the upcoming elections and the developments in the eastern and western parts of Germany. We will fail magnificently to reach the 2020 climate targets" (DE2)	2
Manufacturing & supply chain	Importance of utilising German manufacturing sector for new energy policy and green change as opportunity for German manufacturing	"Especially in the aftermath of the financial crisis, we realised how important the value chains/value cycles within the industry and with medium-sized companies are – how much of an advantage that can be for us. So now [...] we are looking on energy policy much, much more from an industrial policy perspective. And when it then comes to promoting the Energiewende, one of the issues is of course: How many of the technologies that we need for the Energiewende are even available in Germany? Then we say, almost everything is available and we have many suppliers." (DE10)	5
Innovation, R&D	Targeted R&D as important for the growth of the German solar industry.	Public R&D funding is extremely important in order to make sure that the technology development is really taking place in the country where you want to have it... it is absolutely a key element and there is a PV story between 2002 and 2012, it was a big success story which showed that it really worked"	5

Figure 3: characteristics of industrial policy in UK

	Point	Illustrative quote	Number of interviews
Traditional	The UK has not had industrial policy for past three decades	"[The treasury] has constantly set its face against the notion that we should have regional or industrial strategy" (UK8)	7
	New re-emergence of UK industrial strategy as supporting existing industries	"the industrial strategy is very light on specifics...especially on solar...nor is there any real suggestion that the government is going to herald a wholesale shift to, away from big subsidies for offshore wind and nuclear." (UK3)	4
Green	A lack of an industrial policy dimension to energy policy in the UK	"We said 'Look, we can turn the south west into an astonishing hub of industrial activity to power the renewable revolution', and never got even the remotest indication that Treasury was interested in that scenario." (UK6)	5
Instruments	Lack of specific identifiable industrial policy instruments in relation to the energy sector in the UK	"You had a kind of ad-hoc, the market will decide, which might be considered as industrial policy, I'm not sure. It's not really a policy to just allow things to happen. I think as a result of that we do have a bit of a mismatch in terms of what energy we have" (UK2).	5
Skills, job, and trade union movement	A lack of trade union involvement in decision making on energy transitions compared to other countries	"...the European model doesn't apply in Britain, does it? The social partnership which is so prevalent in Germany and in Finland, where the natural thing for governments to do is to be seen to be in discussion with unions and with industry around the same table. I don't want to over-romanticise this, but that is the norm...It's not normal in Britain" (UK7).	3
Manufacturing and supply chain	Missed opportunity for rebuilding UK manufacturing supply chains around renewables	"At that time and a little bit before, the previous ten years or so, the UK shipbuilding industry had been in decline. There's a company called John Brown for example up in Scotland, would have been in an ideal position to take on the whole idea of building wind turbines and systems...it was a missed opportunity because the mindset was wrong. No one could ever believe, and I still don't think they believe, that renewables could actually meet 30-60% of our power needs" (UK4)	3
Innovation, R&D	Lack of R&D support for energy over past three decades	"Post-privatisation, the dominant trend has been [sweating] assets and cutting down on research and development...there was an early awareness of the need to deal with carbon emissions...uch of that R&D went out of the window after privatisation of asset sweating." (UK7)	3
	Increasing R&D in recent years towards potentially disruptive technologies	"they've started funding things that are potentially disruptive. They have started doing smarter grid demonstration and started to support a whole portfolio of renewable technologies, whether directly by government or by agencies...Now we have this Energy Systems Catapult, which is the latest one." (UK1)	2

Denmark

Given that the timing of Denmark's renewed focus on strengthening Danish industry after the 1970s coincides with the strategic support of the Danish wind technology, suggesting that the Danish energy transition was tied to industrial policy-related aims from early on. Denmark had incentive schemes around the development of a wind turbine industry for considerable time. Early subsidy and incentive schemes were mentioned by seven interviewees. Also during this time, it was pointed out that the government signed the first agreements with major utilities instructing them to invest in wind power, and four interviewees even described these activities as the state *"forcing"* Danish utilities to focus more on renewables. The recognition by interviewees of long-term state-led support for the wind industry is also noted in the literature. As Karnøe and Garud point out, (2012: 733), from an early stage in the 1980s in the context of considerable public and political concern around climate change and sustainability, *"state intervention"* was a key feature of the Danish transition from the beginning, where *"State intervention also encouraged research and experimentation across geographically co-located entrepreneurs and it was also involved in the*

setting up of an approval of wind turbine designs by a test and research station. In sum, state intervention stimulated both demand pull and technology push.” (733).

While the Danish interviews did not provide insights in terms of broader reflections on the role of traditional industrial policy in Danish policymaking. However, many things discussed related to key instruments of industrial policy oriented around renewables in particular wind, suggestive of *green industrial policy*. Elsewhere, however it has been noted that industrial policy has been an important dimension of Danish policy-making. As Campbell & Pedersen, (2007: 321) argue “...*Denmark embraced industrial policy*” where due to lacklustre performance of the Danish economy in the 1970s “*the government devised an industrial policy aimed at improving the technological capacities and, therefore, the competitiveness of Danish firms in world markets*”. However, this was fundamentally oriented around the kinds of procedures of ‘negotiative democracy’ discussed in the context section, comprising “*an institutionalized strategic collaboration between various actors from the private sector and government—a discovery process where firms, unions, other interest groups, experts, and the state learn about costs and opportunities and then engage in strategic coordination*” (ibid: 323). It is worth emphasising that such a policy approach stands in stark contrast to the market-driven approach of the UK discussed below (Hancké & Coulter, 2013).

Germany

Understandings of the role that industrial policy plays in Germany more generally, definitions of what constitutes industrial policy, and the role of green industrial policy in Germany varied considerably. Given that in current media discussions around UK industrial policy Germany is often cited as an example of successful industrial policy (Chang, Andreoni, & Kuan, 2013), and prominent economists note that “*it is fair to say that it [Germany] has one of the most active industrial policies in Europe*” (Pegels & Lütkenhorst, 2014a), the divergences that emerged in interviewee responses regarding the role of industrial policy in Germany more generally, and the energy transition more specifically was striking. Three interviewees highlighted that industrial policy was a ‘controversial’ or ‘ideologically loaded’ term in Germany. For example, one interviewee stated that “*...in Germany the debate was also a little bit not so outspoken about industrial policy because it is still a controversial paradigm. Not controversial in doing so, but controversial in naming it*” (DE11, Research). Another interviewee pointed out that there was hesitance in Germany around industrial policy because it is a “*very ideologically loaded term*” (DE5, Think Tank). Another interviewee drew attention to the fact that as German political culture was very much centred around the idea of a ‘free market’ “*one has to be very careful*” in using the term industrial policy “*since if there’s a free market, then it can’t be controlled in that way*” (DE Interview 4, Utility). Another interviewee highlighted that politicians in Germany are “*fearful*” about stating they are pursuing an industrial policy in case it appears they are “*Select[ing] technological winners and losers*” (DE3, Research).

The Energiewende has been identified in the literature as an example of ‘green industrial policy’ (BIS, 2013; Cox, Johnstone, & Stirling, 2016; HM Government, 2012, 2013a; Stirling & Johnstone, 2018). Yet, responses on this topic were also nuanced. For one interviewee, the role that industrial policy has played in the Energiewende has been “*a very central one*” understood as actions taken by Government to “*deliberately build up an industry*” (DE3, Think Tank). Another interviewee, noted that “*a very important justification of the Renewable Energy Act that would have its benefits in*

providing or driving competitive, innovative, future-oriented industry in Germany” (DE Interview 6, Research). Another interviewee noted that “The energy industry sees itself as a part of industrial policy, of course, and their business model has been affected drastically through massive interventions from the federal government” (DE Interview 10, Industry Association). While long-term interventions like the Feed-in-Tariffs under the EEG and earlier interventions like the 100,000 roofs programme for solar are well known, others stated that this in itself did not directly constitute a ‘green industrial policy’ but rather these policies were more implicitly beneficial to certain industries rather than being concerted industrial policy. For example, an interviewee noted that “the EEG has industrial policy effects, but is not really an industrial policy instrument, but an energy-economical instrument.” (DE15, Trade Union).

It seems that German industrial policy in terms of the Energiewende is a nuanced affair, and requires looking at other dimensions to understand it further. An important part of these relates to *policy instruments* related to coordination measures. Here it is less about explicitly stated green industrial policy but rather what two interviewees identified as crucial elements in German green industrial policy in terms of *“creating economic framework conditions that enable companies to operate competitively on an international market”* (DE15, Trade Union) , or as a interviewee from a Government ministry states: *“industrial policy. Of course we always consider and include this in the coordination processes: what does it mean when we turn the industrial policy lever? What effects does this have for the companies in Germany? From the head of the ministry to the single departments this is being considered”* (DE Interview 13, Government Ministry). Other types of coordination are provided by the framework conditions established in the long-term policies around the EEG. As stated by one interviewee *“...the industry also has a clear need for reliable conditions for investments, and to have a successful Energiewende you need to safeguard investments so that people actually invest in the Energiewende itself”* (DE5, Think Tank). As discussed in table X other important coordination measures in Germany include export initiatives and coordination of platforms around new technologies such as battery storage and electric vehicles.

UK

On the theme of *Traditional industrial policy* there was an understanding shared by five interviewees that for the past several decades the UK has effectively had no industrial policy. A UK politician put it simply that “I'm not convinced there really has been industrial strategy in the UK for probably kicking on for certainly more than my lifetime [between 30-35 years].” (UK 2, Politician). Elsewhere it was stated that “the traditional British view, at least since the optimism of the '60s, has been: ‘We don't do industrial policy. It just messes things up” (UK 1, Research). This lack of industrial policy in the UK replaced by the dominance of a market-oriented approach is recognised in the literature (Craig, 2015; O'Sullivan et al., 2013). Although, this is slightly nuanced around the idea that the UK's industrial policy related to the more general aim of ‘competitiveness’ rather than more directly supporting industry (Beath, 2002; Wren, 2001) All interviewees felt that industrial policy had not played a role in the UK's energy transition thus far.

However, there are two exceptions to this trend in the energy domain in terms of offshore wind and nuclear power. In terms of offshore wind, One interviewee stated that *“the likes of offshore wind had a place in the last industrial strategy, I’d be shocked it if didn’t have a place in this industrial strategy”* (UK 5, Think tank). There is evidence to suggest that offshore wind is an area where the UK has been deploying industrial policy *instruments*. The UK government has worked closely with the industry undertaking a “strategic framework for the offshore wind industry” since 2002 (DTI, 2002). Despite being the most expensive form of conventional low carbon generation, the UK government continues to support offshore wind through Contracts for Difference (CfDs) in place, while support for other renewables have been cut in 2015.

More specifically related to industrial policy however, in 2009 investment was made by Government to encourage manufacturing of blades for offshore wind turbines to boost ‘green jobs’ (Mullholland, 2009). *Coordination* measures such as the setting up of the Offshore Wind Developers Forum in close contact with state institutions also indicates that industrial policies are present in this domain. There has been a clear focus on the value of offshore wind for UK jobs and manufacturing industries, with the publishing of an ‘industrial strategy for offshore wind’ specifically designed around increasing the role of UK *manufacturing* in the offshore industry (HM Government, 2013b). The state has collaborated closely with Siemens to enable the opening of the blade construction facility in Hull, which opened in 2016. Additionally, targets of 50% UK content for offshore wind was set (BVG Associates, 2013) with estimates that higher shares could be reached (BVG Associates, 2014). It was announced by government that future offshore wind developments will “require” British local content in future where developers will need to demonstrate how an offshore wind proposal benefits the “UK supply chain” (Weston, 2016). As discussed elsewhere, nuclear power seems to be an especially privileged technology in terms of Governmental priorities and in terms of policies aimed at stimulating the skills base since 2006 nuclear power seems to have been a rare point (along with offshore wind) of dedicated governmental policies around specific training needs and bolstering the supply chain (BEIS, 2017b).

Recently however, there has been a notable shift in UK policy making towards “industrial strategy”. Jones, (2016: 828) notes that an apparent *“rediscovery of industrial policy”* by the British Conservative Party is driven by *“...a near-terminal collapse of the financial system and several decades of de-industrialisation. It re-emerged under conditions of high public and private debt, a large trade deficit, and huge regional inequalities”*. The Labour Party also set out an industrial strategy (Labour Party 2017: 3). Interviewees were uncertain about the implications of this industrial strategy for energy. There was concern that while resource productivity and energy costs are important, there was not enough focus on technologies in which the UK could seize opportunities for new global products: *“The industrial strategy should be looking at technologies where we have the potential to play a world-leading role. At the moment that looks to me at being marine renewables of all forms... What the UK will go for I think is more of the same.”* (UK 2, Politician). While there has been a consultation, so far the approach indicated has been for “sectoral deals” with the nuclear industry receiving a sectoral deal but with renewables not being mentioned as key priorities in the same way that nuclear is in the industrial strategy documents thus far (BEIS, 2016; BEIS 2017). As three interviewees pointed out, there is the potential for more green industrial strategy through the *innovation & R&D policy* being outlined within the UK’s industrial strategy, where there are signs of increased funding for ‘Smart’ technologies, electric vehicles, and battery

storage R&D programmes (Pegels & Lütkenhorst, 2014; Rutten, 2014). To summarise, the case of the UK sees a lack of industrial policy historically in terms of the UK energy transition for the past thirty years. There are signs of an implicit industrial policy around offshore wind in the UK and industrial policy around the incumbent technology nuclear power.

4.5. Interplay between industrial policy and disruptive innovation in Denmark, Germany and the UK

In this section, we now turn to two aspects of the interplay between industrial policy and energy system disruption, starting with research question 2a on industrial policy as enabler or barrier to disruption, and then turning to changes in industrial policy in response to energy system disruption.

Figure 4: Overview of disruption and industrial policy in case study countries

	Status of disruption	Status of industrial policy
Denmark	Decentralisation of energy infrastructure through large growth of onshore wind since the 1980s. Potential 're-centralisation' of energy ownership through growth of offshore wind.	Prominent role of industrial policy in Danish energy transition. More direct and 'vertical' interventions by state actors to direct industry towards more green.
Germany	Three identified phases of disruption gathered from interviewees: First electricity disruption (particularly disruption of business models, ownership) Second electricity disruption (further disruption of electricity towards consumer level facilitated by battery storage and digitisation) Cross sectoral disruption	Disagreement between interviewees regarding whether the EEG represents industrial policy or not. Early support measures for wind and solar leading to disruptive change seen by some as representing industrial policy components and by others as being an economic instrument with industrial policy effects.
UK	Technological disruption, challenges of grid integration. large growth of renewables particularly offshore wind; but limited disruption of regulation, business models, or ownership.	Industrial policy has not played a central role in UK for past 30 years. Green industrial policy not thought to have played a role in energy transition. Industrial strategy around offshore wind and nuclear. Renewed interest in industrial 'strategy' in 2017, uncertain directionality in terms of traditional and new industries.

4.5.1 Industrial policy as enabler and barrier to disruption

Industrial policy as an enabler

Denmark

The decentralisation of energy supply in Denmark is considered as representing a disruption by seven interviewees. In this regard, eight interviewees noted the importance that long term government subsidy and support to stimulate the wind industry from 1979 onwards, as well as actions taken in the 1980s influencing companies to switch to biomass, played an important role in enabling this disruption. The associated factor of this industrial intervention being geared around the importance of a 'long term' vision based on a renewable future, is a compounding factor in considering the Danish energy transition as an example of green industrial policy. The key role

played by the State in coordinating the acceleration of investment in wind on the part of Danish utilities in the 1990s, the key role of policies to support wind turbine manufacturers in the 1990s, all relevant factors suggesting that industrial policy played an enabling role in energy disruption in Denmark.

There are other points that indicate important linkages between industrial policy and energy system disruption that could be considered as enabling factors. Five interviewees pointed towards the importance that job creation had played in the Danish energy transition. For example, one interviewee discussed the role that the Danish energy transition played in reinvigorating the Danish Shipyards. Another example concerns the dialogue between politicians and trade unions in the 1980s which focused on the value of disruption in terms of jobs created through the shift from fossil to renewable technologies. As stated by one interviewee, this focus made the key stakeholders of trade unions to be generally supportive of the Danish energy transition.

Another related factor mentioned by one interviewee was the important decisions taken by DONG energy when (influenced again by the State), decisions were taken to split the company between remaining fossil assets that were sold off, and the core business based around offshore wind. There was concern about job losses and loss of high skilled jobs related to coal fired power. In order to manage this process however, efforts were made to sell off the coal expertise to other countries who were still involved in coal fired power construction. While questionable from the perspective of embedded emissions, it could be posited that this strategic approach to skills and expertise related to fossil fuel assets enabled accelerated disruption in the energy sector to take place, through avoiding some of the negative externalities of structural change.

Germany

Although green industrial policy is recognised as an important enabling factor in driving the German energy transition in some literatures (Jacobsson & Lauber, 2006), in terms of the ‘first wave’ of disruption in Germany, only four interviewees expressed that industrial policy was a central driver of the initial transformation of the German energy system. For example, one interviewee noted that industrial policy has played a *“big role”* where *“it was a very important justification of the Renewable Energy Act that would have its benefits in providing or driving competitive, innovative, future-oriented industry in Germany”* (DE6, Research). However, relating back to the ‘controversial’ nature of industrial policy in Germany, others pointed out that the EEG *“...is an energy-economical instrument. It is not specifically an industrial policy instrument”* but it had *“industrial policy effects”* (DE13, Trade Union). These ‘effects’ were pointed out by others for example the importance of new job creation in German industry played. As pointed out by one interviewee, *“a very central idea was to create jobs and establish new players and industrial jobs that will also benefit Germany”* (DE1, Research). One interviewee made the point that industrial policy had not played a role in the early days of the first wave of disruption in the 1990s, however as the wind industry grew, *“It became important, or it became symbolised because you suddenly could picture companies offering new jobs. You could picture export statistics. Basically, the idea, well, that our jobs of the future clearly played a beneficial role in the balancing of a political fight about continuation of a policy”* (DE11, Research).

The topic of wind, and in particular the emergence of offshore wind was an area where industrial policy was more clearly articulated according to three interviewees. This particularly relates to regions in which policies are geared around reinvigorating regions dominated by ship building to ensure they benefit from new industries based around offshore wind. As discussed by one, there are *“projects motivated by industrial and structural policy”* in order to *“...create synergy effects for these regions and thus organise the transition of job losses from the ship construction towards new occupations”* (DE15, Trade Union). However, given the ownership structures of the offshore wind industry, dominated by large utility companies, it can of course be questioned as to the extent to which this particular industry is ‘disruptive’. As well as the jobs, through *“market creation”* through the EEG (FIND) that the German manufacturing industry could serve was also noted by some as relating to industrial policy in that *“a stable market...enabled the development of an industry”* (DE15, Trade Union). The creation of a domestic market through governmental intervention in the Energiewende is well noted in the literature (Gutermuth, 1998). Similarly, while not necessarily mentioned by interviewees much, also noted in the literature is long-standing state-led interventions such as the 100,000 roofs program for solar, investment cost grants, favourable loans, and tax relief, that played a crucial role in building up an industry that could serve new emerging markets that were being created (Nolden, 2013). Such an active role of policy measures taken by the state to stimulate industry would have not been possible within the policy paradigm of the UK at this time period for example. However, although important, in the case of solar, and pointing out the problems that faced the German solar industry in terms of competition from China, one interviewee argued that there was in fact a lack of industrial policy: *“So the German problem was Germany created the market but did not dare to have what is called industry policy that needs people to support industries”* (DE7, Research).

UK

To recall, it was posited that the UK has not seen the kind of disruption of market & business models or ownership that characterises the substantive changes that have taken place in Germany and Denmark. The UK faces technical and regulatory disruption in terms of changes to grid management and infrastructure. However, as discussed above, overall industrial policy has not thought to have played a key role in facilitating the emergence of energy disruption in the UK. In terms of low carbon electricity and renewables where the UK has pursued industrial policy is in the area of offshore wind, however offshore wind was not identified by UK interviewees as being disruptive in the same way in which more decentralised renewables can be. One interviewee even stated that *“Do you count a 2GW offshore wind farm as a decentralised energy? That feels a lot like centralised energy to me”* (UK4). As has been written elsewhere, large offshore wind projects are thought to be less disruptive on centralised grid infrastructures (HM Government, 2017b) and the large upfront capital costs associated with offshore wind developments mean that existing large scale utilities are usually involved in these projects and there are less opportunities for community or cooperative models associated with these developments. However, through coordination measures, financial incentives, and specific aims to stimulate UK supply chains around offshore wind, this is one area of renewables development in the UK that can be understood to have had an industrial policy aims and directions. However, as discussed below this may be more read as industrial policy around technologies that sustain rather than challenge existing business models and ownership structures. However, in 2017

developments have seen the UK Government specifically discuss ‘clean technology’ and ‘disruptive technology’ in the context of the UK’s new “*industrial strategy*” where there are R&D funding arrangements targeted at electric vehicles as well as flexible “smarter” “demand side response” measures which could potentially be disruptive (HM Government, 2017b). However this remains to be seen.

Barriers

Denmark

In terms of *barriers*, seven interviewees raised concerns that the increasing strategic importance of the wind industry to Denmark and the strong levels of state control in facilitating this industrial expansion, has centralised production into the hands of fewer large companies. The industrial expansion and improvements in production methods assisted by the State through the provision of test fields and R&D has seen the traditional local production and local ownership models challenged, with increasing conflict around siting and financial remunerations from wind power production. For some, the increased steering and involvement of the state in the wind industry of Denmark represents a centralising process challenging some of the original grassroots and decentralised approaches that motivated the Danish energy transition originally. Industrial policy in the 2000s in Denmark has arguably been about stabilising an emerging regime into the hands of fewer corporate entities with increasing involvement of international finance, and thus may be prohibitive to some aspects of the disruptive process in terms of decentralisation and ownership models.

Germany

Further discussions around industrial policy regarding the balance between traditional and green industrial policy reveal more nuanced answers regarding enablers and barriers. This particularly relates to the question of policies around the protection of existing industries and whether this constitutes an enabler or barrier. Two interviewees saw that some protective measures involved traditional industrial policy had the effect of potentially slowing disruptive change. One interviewee pointed out that “...*there are going to be winners and losers. The losers – the steel industry, the chemical industry, the nonferrous industry, to name a few examples –are politically very strong*”, leading to “...*a giant discrepancy between the stated political aims, the noble pronouncements and the measures taken.*”(DE2, Government Ministry). This includes measures for energy-intensive industries such exemptions from the EEG surcharges for energy intensive industry and carbon exemptions, and these measures according to one interviewee that the reactive traditional industrial policy has played more of a role than green industrial policy in terms of the current German energy transition (DE5, Think Tank). The need to protect existing industries can also be seen as an enabling factor however, as two sides of the same coin of industrial policy. One interviewee noted that “...*you have to see that the competitive conditions fit somehow and the burden does not become too big there, because the logic from an environmental perspective is: the material is needed, not only for the Energiewende, but also for other sectors, and it’s needed globally*” (DE12, Ministry). This is an important point drawing attention to the fact that if German manufacturing and industry such as steel is to underpin the material basis of the Energiewende, then ‘green’ and ‘traditional’ policy are two sides of the same coin in terms of some existing energy intensive industries underpinning the new ‘green industrial policy’ and requiring the maintenance of their competitive status in the face of

global competition through protective measures. As another interviewee noted, *"I think that for this issue of structural change towards the target of ecological industrial policy or sustainability we need both: to make these new sectors competitive and also to make sure that due to the support for renewables, which for example has effects on electricity prices, an energy-intensive industry doesn't just move away"* (DE15, Trade Union).

Thus the demarcation between enablers and barriers with regards to the balance between 'traditional' and 'green industrial policy' is by no means clear cut. Fundamentally, then, German industrial policy relates precisely to the decision making sphere, coordination measures between the two sides of industrial policy and what actors have more or less of a role in influencing the direction of industrial policy. A dimension of industrial policy relates to the world of work, and the role that trade unions play in the decision making sphere. While IG Metall is a union firmly on board with the *Energiewende* others are not. This was a point in terms of *barriers* pointed out by four interviewees, that trade unions and industry associations surrounding lignite mining and coal fired power production, as well as some energy intensive industries, had powerful lobbying powers in terms of influencing the 'balance' in terms of protective and more proactive green industrial policy. As one interviewee noted, *"In Germany the IG Metall is a very progressive union which has realised the opportunities coming from the disruptive transformation of the energy system... Whereas the union which is responsible for mining...are very backward minded"* (DE7, Research).

UK

It was suggested in four interviews lack of industrial policy in the UK was a barrier to disruption in the energy sector. As one interviewee put it: *"one would have to say that the approach to industrial strategy...formulated towards the end of the last century and then reinforced through the first decade of this century has been incredibly unhelpful for renewables"* (UK 6, NGO). Connected to this idea is the dominance of the UK Treasury, as stated by one interviewee, which had *"...constantly set its face against the notion that we should have regional or industrial strategy"* (UK 8, Consultancy).

This lack of a regional industrial focus was mentioned by four interviewees, and is relevant because it was at the regional level where ideas around industries based around potentially disruptive energy technologies were based. As one interviewee put it: *"We'd say, 'Look, we can turn the south west into an astonishing hub of industrial activity to power the renewable revolution', and never got even the remotest indication that Treasury was interested in that scenario."* (UK 6, NGO). A lack of industrial strategy was associated by four interviewees as an important dimension in the 'lack of vision' around a different energy paradigm for the UK.

Several interviewees reflected on the UK's recent considerations of industrial strategy, which is not designed to enable energy system disruption. Three interviewees pointed out a lack of clarity regarding the industrial strategy. One interviewee noted that the *"the industrial strategy is very light on specifics...especially on solar"* and *"nor is there any real suggestion that the government is going to herald a wholesale shift to, away from big subsidies for offshore wind and nuclear."* (UK 3, Trade Association). A politician argued that the industrial strategy was focussing on familiar technologies rather than on *"technologies where we have the potential to play a world-leading role"* such as 'marine renewables' and 'floating wind farms' (UK 2, Politician). Three interviewees noted that the industrial strategy appears to be more about lowering costs for existing industries rather than

promoting new technological trajectories. As discussed above, the apparent prioritisation of the UK Government towards nuclear power and offshore wind was mentioned by five interviewees. It was pointed out that incumbent sources of energy, particularly nuclear power, appeared to have a privileged position in the proposed industrial strategy, with potential consequences of curtailing disruption.

However, two of four interviewees pointed towards the changing nature of innovation policy (a potentially important strand of industrial policy) as a place where *“they’ve started funding things that are potentially disruptive.”* (UK 1). This last point is potentially backed up by developments in UK policy in July 2017, where the British government have allocated £45 million to open a ‘battery storage research centre’ to bring down costs and make Britain a leader in battery storage technology, with a ‘mission oriented’ approach based around a competition named the ‘Faraday challenge’ (OFGEM, 2017). This is part of a phased long term investment of £246 million for battery storage technologies, announced to coincide with plans by OFGEM and Government to build towards a more flexible energy system (BMW, 2018). This was widely welcomed by a range of energy experts and by some as a ‘game changer’ in UK energy, possibly signalling greater planning and State commitment towards disruption in the energy sector. These announcements occurred after the interviews had taken place however, so were not mentioned by interviewees.

4.5.2 Changes in industrial policy due to disruption

Denmark

From the Danish case, there are two key points where disruption has potentially influenced industrial policy. First, it is important to recall the key role of local and cooperative actors in driving initial disruptive changes in the 1980s, combined around the strong vision of the ‘Alternative Energy Plan’ based around a shift away from plans for nuclear power towards renewables, in driving change in the energy sector of Denmark. As five interviewees highlighted, without this pressure from the grassroots it may be that the state-led long-term interventions (which we argue in this paper constitutes a green industrial policy) would not have occurred. Therefore, disruption of dominant business models and ownership structures through challenging the incumbent energy trajectory pressured the state to take more facilitative action through industrial policy measures to stimulate a new industrial pathway. It does appear through the consistent political commitments and direct political involvement during the 1990s, entails that the energy disruption changed from being viewed as a ‘threat’ to being viewed as an ‘opportunity’ for stimulating and reinvigorating Danish industry and manufacturing at a time when other industries (for example shipbuilding) were in decline.

Disruption entails the restructuring of industry with potentially significant consequences for employment and skills activities. Suggested by evidence in the interview data the energy disruption and the restructuring of industry away from fossil fuels, has also influenced strategies to manage the decline through industrial policies. This is seen in policies designed to simultaneously softening the blow of job changes while again accelerating transformations in offshore wind by providing the test facilities required to bolster an emerging industry.

Germany

In Germany, there are two ways discussed here in which disruption may have led to changes in industrial policy. This relates to the consequences and costs of the ‘first wave’ of electricity disruption and the costs associated with the growth in renewable energy and the implementation of protective measures for traditional German industries such as chemical and steel industries. The second, relates more to new technologies in the second and cross-sectoral disruptions, associated with fears around German industry losing industrial potential in terms of changes in battery storage, digitisation and electric vehicles. Six interviewees highlighted changes in instruments that had come about to manage the disruptive effects of the EEG and Feed-in-Tariff system which has led to increases in electricity prices. This relates to what was described as the “reactive” side of industrial policy described above (DE *“...you have to see that the competitive conditions fit somehow and the burden does not become too big there, because the logic from an environmental perspective is: the material is needed, not only for the Energiewende, but also for other sectors, and it’s needed globally. This means, when we say we create conditions that do not allow the steel industry to operate competitively here, then the quantities that are not being produced in Germany will simply be produced elsewhere.”* (DE12). This relates to specific instruments used in Germany as part of the EEG known as the “special equalisation scheme” where energy intensive industries do not have to pay the full EEG surcharge or are exempt from it. This is being updated for the future to be in line with EU law, where the “special equalisation scheme” will only apply to companies that compete internationally. The rationale behind this scheme is clearly stated by the German Government: *“It is vital that the competitiveness of electricity-intensive industries - which already pay high electricity rates in comparison to their international competition - and the jobs provided by these industries not be jeopardised.”*(BMW, 2018)

Discussion on industrial policy measures around the technological dimensions of the second and cross-sectoral disruptions in Germany were also mentioned by interviewees. This centred around active policies being pursued by the German Government to ensure German industrial involvement in key supply chains around technologies including battery storage, electric vehicles and digitisation. As discussed by five interviewees this relates to the broader context of particularly China advancing in areas of technological developments and Germany and more broadly Europe being left behind. As stated by one interviewee *“China is becoming one of the leading economic nations – it’s already one today – and the question is: what role will Europe play? Will Europe fail to get on board?... will Europe manage to take part in this phalanx? Currently, it does not look very good for Europe”* (DE2). However there were concerns that in terms of R&D responses for new disruptive technologies not enough targeted R&D for new technologies was being provided. As one interviewee stated *You only have to look at our research and development. “Much money is flowing into areas that have achieved nothing, while forward-looking areas are being neglected”* (DE2). Another interviewee also agreed with this point, arguing that *“at the moment the high-tech strategy has no very strong component in the direction of greener, you know the high-tech strategy at the moment is very broad about Nano technology, new materials. I really don’t see more than lip service to the needs of the energy transformation process”* (DE7).

They also similarly pointed out that German industry was set to be disrupted by the changes to electromobility because the pace of investment and change towards electric vehicles by German automotive sector that *“This disruptive transformation of the automotive sector is an issue which is very, very dangerous for certain companies, thanks to the country of Germany, Germany’s economy*

is very heavily committed to improve the automotive sector. It's a very important part of the economy and in Germany the transformation to electromobility is lacking strongly behind other countries." (DE7). However, other interviewees noted that important developments were occurring in terms of investment by Government in The German High Tech Strategy, and R&D around platforms for electric vehicles and batteries. The German Government have more recently explicitly stated a "modern industrial policy" based around sustaining competitiveness of German industry by targeting areas as part of high Tech Strategy including "key enabling technologies" such as electromobility and highlighting that "if Germany wants to remain a premium car manufacturer, Germany needs to be able to manufacture its own battery cells" (**). This emphasises a potential response via industrial policy to "adapt and evolve" to the disruptive consequences of technological change.

UK

With respect to innovation policies and planning for future technological change, four interviewees noted that disruption in the UK was being at least taken more seriously by Government from an industrial angle, with new institutes such as the Energy Technologies Institute set up and recent announcements put in place for increased funding around battery storage and flexibility. This is perhaps suggestive that disruptions 'on the horizon' in the UK (and clearly visible in countries like Germany) are influencing more strategic interventions by the State to prepare for the disruptive changes of the future. While there is disagreement as to whether offshore wind is a point of disruption, mentioned by seven UK interviewees and also identified in the literature (HM Government, 2013b), it is clear that the offshore sector has been the recipient of over ten years of strategic state support through Contracts for Difference financing arrangements. However, there are also signs of more strategic support for the manufacturing sector around the offshore wind construction sector through facilitating the Siemens blade turbine factory in Yorkshire, and more recently, 'local content requirements' for offshore wind developers. Such actions constitute an implicit 'industrial strategy' around offshore wind (Green Alliance, 2016). Therefore, in response to the changing industrial landscape as part of a broader 'clean disruption', it may be that opportunities in offshore wind have influenced a more industrial policy focus by the UK government.

However, another theme that emerged from the analysis was concerns raised by three interviewees that the 'industrial strategy' considered in 2017, did appear to be oriented more towards lowering costs for existing producers where there was little mention of key renewables (apart from offshore wind) with the climate change issue also not playing a central role. This concern is compounded by two other factors raised by interviewees: one, is the 2015 decisions where a range of policy support mechanisms were withdrawn around solar, onshore wind, and energy efficiency, resulting in significant job losses and an apparent loss of confidence with regards to investment in these technologies (Garud & Karnøe, 2003). The second, noted by three interviewees, was the strong, long-term support given by the UK government for nuclear power, including changes in planning law, the setting up of skills institutes around nuclear, the provision of 'guaranteed loans' for investors, 35 year index linked guaranteed price for electricity, and R&D priorities for bolstering the British supply chain through Small Modular Reactor development. Thus, it is a possibility that industrial policy has also emerged in response to emerging disruption, in order to give the support necessary to preserve certain strategically important technological areas given the presence and continued growth of low carbon competitive technological alternatives.

5. Discussing six propositions on the interplay of disruption and industrial policy

After having presented our findings on the different building blocks of our analytical framework and their interplay, we now turn to a discussion of six propositions arising from our findings for the two case study countries to stimulate further discussion and research.

5.1 Directed industrial policy as enabling disruptive change

The case of Denmark showed that while decentralised ‘bottom up’ local initiatives were important in driving the development of disruptive change, the State played a crucial role in intervening to assist in nurturing a long-term research environment for wind energy. From a very early stage, the state assisted through subsidizing manufacturing, then subsidizing production, as well as intervening to form policies requiring the purchasing of wind energy by utilities, as well as intervening to implement switches from coal to biomass from the late 1980s onwards. With the collapse of the Californian export market in the 1980s, commentators believe that the Danish wind industry may have collapsed without this long term state support (Lütkenhorst et al., 2014). In Germany, while interviewees disagreed about the extent to which the German *Energiewende* constituted industrial policy as is often stated in the literature (Pearson & Watson, 2012), some felt that the supportive measures involved in the EEG at least had ‘industrial policy effects’ contributing to the deliberate building up of an industry. These factors in Denmark and Germany, combined with long term goal setting around wind energy targets from the early 1980s, displays clear state coordination in guiding and shaping the wind and biomass industries in a way that simply was not present in the UK until many years later.

5.2 Lack of industrial policy as hindering disruptive change

A complementary finding to this arises from the case of the UK, where interviewees generally argued that disruption had not taken place in the UK on a systemic level. It was pointed out, that the energy system remains largely centralised and based around key incumbent utility companies, where unlike in Denmark local and cooperative ownership is minimal. In addition, the growth of renewables in the UK has occurred at a later stage than Denmark. There were not the early subsidy schemes for investing in wind energy in the 1980s like in Denmark, or the long-term R&D assistance from the State. Many initial policies such as the Non-Fossil Fuel Obligation (NFFO) were not targeted at a specific industry but were neutral and related to low carbon, thus mainly benefiting the incumbent nuclear industry (Berry, 2016). The UK did not employ direct support in the form of Feed-in-Tariffs targeting specific technologies until 20 years after Denmark, and there was no mention in the interviews and literature of comparable levels of state involvement in accelerating industrial change towards renewable or low carbon industries as occurred in Denmark in the 1990s. Many participants also spoke of the lack of long-term vision, which contrasts markedly with Denmark, and a lack of clarity regarding the direction of travel for the energy sector. In fact, it was mentioned that through a lack of long-term political support, important manufacturing capabilities in UK wind energy were lost in the 1980s at the time when the Danish industry was slowly being built up through governmental support. This picture fits with more general observations of the lack of an explicit (green) industrial policy in the UK compared to other countries (BMW, 2018), which appears to at face value and in the minds of interviewees, correlate with notions that many characteristics of disruption are not present in the UK energy system.

5.3 Industrial policy as managing disruptive change

A key example of this was in terms of the ‘two sides of the coin’ of industrial policy in Germany, and how protective measures had been brought in to protect existing energy intensive industries from the originally high costs of the growth of wind and solar power in the generation mix. This was done through energy surcharge exemptions for energy intensive industries under the , done specifically in order to protect the international competitiveness of German industry (Mendonça, Lacey, & Hvelplund, 2009). This was done over fears that German industry would be harmed and relocations would occur because of the associated increasing costs of the growth of renewables and environmental policy measures.

There is some evidence stated by interviewees in Denmark and Germany and backed up in the literature (Andreoni, 2017), that there has been more involvement of key stakeholders including trade unions related to issues around the negative consequences of disruption in terms of skills and employment. There is evidence that from the 1980s that as in the case of the declining shipyards in Denmark, arguments were put to key stakeholders such as trade unions (particularly in the 1990s under the Social Democratic central push towards renewables) that the development of wind energy and replacing fossil fuels were beneficial from a jobs and skills perspective. Here, the potential of renewables was framed as an opportunity rather than threat to employment. While the evidence is not substantial, there are signs of the greater importance of unions, questions around jobs and skills, and supply chain and manufacturing in the energy transition of Denmark, as befits important characteristics of varieties of industrial policy (Foden, Fothergill, & Gore, 2014; Skidelsky, 2013).

In terms of Denmark, there was also evidence that when the Danish State pushed key stakeholders such as Dong energy to divest from coal assets towards focussing on wind energy, important decisions were made to export skills and expertise around coal to other countries, thereby sustaining the skills and expertise in this area and presumably moderating job losses incurred through a transition from fossil fuel to renewable energy systems. This arguably contrasts significantly with the case of the UK where the rapid closure of coal mining activities and industrial activity over the past thirty years is thought to have led to a notable loss of skills and unemployment (Phil Johnstone & Hielscher, 2017). In the UK’s coal phase out consultation of 2016, key concerns that emerged were that insufficient planning had been done around issues of job losses, regional decline and retraining, and key stakeholders such as trade unions were not involved to a suitable degree (Kern, Smith, Shaw, Raven, & Verhees, 2014). This again relates to broader themes beyond the scope of this paper concerning the very different roles that trade unions play in British compared to Danish political culture more generally (Hampton 2015). However this point does highlight the importance of such issues, and the potential role some factors related to industrial policy play in managing the negative consequences of disruptive change.

5.4 Industrial policy stabilising and expanding an emerging potential new regime

There is evidence in all countries of the role of industrial policy in strengthening and expanding an emerging new low carbon technological regime through industrial policy related measures. In Denmark and the UK this related to offshore wind development. However, respondents in both case studies highlighted uncertainties as to whether offshore wind entails characteristics of disruptive change. Nevertheless, what was clear is that there is evidence of industrial policy related actions towards this sector in both case studies. In Denmark, this is seen by the direct political interventions in “forcing” large companies to move more quickly towards offshore wind away from coal assets, and in state provision and funding for offshore wind parks crucial for the development and testing of technology. In the UK, offshore wind has since 2007, received privileged support in the form of subsidy and then Contracts for Difference over a long period of time despite offshore wind being the highest costing form of currently operating renewable generation (Weston, 2016). Such state

directed support has intensified with the establishment of arrangements around 'local content requirements' geared towards bolstering British manufacturing and supply chains in the offshore wind industry (BEIS, 2017a). Offshore wind has been specifically highlighted as central to the UK's recent industrial strategy (Strunz, 2014). In the UK interviews, in fact, one of the few success stories of a green industrial policy discussed by interviewees was the case of the offshore blade turbine manufacturing facility owned by Siemens in Hull, which had been built up over many years through close collaboration between business, local government and even trade unions. So, as well as enabling the emergence of new technological pathways, certain kinds of industrial policy interventions seem to also be important at a later stage in stabilising and expanding supply chains and industrial growth around certain chosen technological pathways. In terms of Germany, the emerging *Energiewende* is widely understood as a 'regime shift' (DTI, 2003). However, while some interviewees felt that there had been industrial policy as part of the *Energiewende*, there was more uncertainty regarding the balance between green and traditional industrial policy in recent years and whether the new emerging regime was receiving an appropriate balance of support compared to protective measures for traditional industries.

5.5 Industrial policy as protecting and maintaining incumbency

The fifth relation between industrial policy and disruption is highlighted predominantly by the UK case, where an emerging potential effect of the UK's rediscovery of industrial policy in recent years may be to protect existing, incumbent industries rather than facilitating disruptive change. In the UK since 2006, there has been a concerted effort on the part of the British State under different political parties to strongly support the nuclear industry, apart from a brief juncture in 2003, when the abandonment of nuclear was considered (Taylor, 2016), before a rapid 'behind the scenes' change of heart (Taylor, 2016), with nuclear reemerging as central to the UK's low carbon strategy (BERR 2008; Johnstone, 2009).

The resurgence of nuclear power, difficult to understand from the perspective of conventional criteria based on economics or strength and performance of industry (HM Government, 2013a), has been accompanied by an array of policy interventions including changes in planning law, speeding up of licensing procedures, the opening of new skills institutes, discussions at an early stage around industrial strategy around nuclear (Cox et al., 2016), and an outpouring of documentation around sustaining skills and expertise in this industry from 2004 onwards (Geels, 2002; Markard et al., 2012). Nuclear power with nuclear power receiving a 'sectoral deal' in the proposed government industrial strategy (BEIS 2017). Simply put, this sustained support over a 12-year period is unprecedented in the energy sector besides from the exception of offshore wind. Some interviewees argued that the high levels of support and maintenance of nuclear power as central to the UK generation mix would hinder or slow disruptive change, however nuclear power could also be considered as important for meeting the UK's climate obligations.

For some German interviewees, in terms of the balance between 'old' and 'new' industrial policy, the protective measures around energy intensive industries, as well as the slow progress being made with regards to coal phase out, was an example of industrial policy protecting incumbent industries at the behest of more 'green' industrial policy in the sense that these measures were overly protected and had the consequence of slowing the speed of transitions. But this point highlights the balancing act between what can be understood as measures to manage disruptive change and measures that are protecting incumbency at the cost of supporting new emerging pathways.

5.6 Disruption paving the way for new industrial policy

The final proposition relates to the potential influence that disruption has on industrial policy. The case of Denmark indicates the importance of long-term policies, state led interventions to influence the directionality of industry, and policies aimed at managing the decline in jobs and skills losses in existing industries. Understood systematically, disruption entails profound changes to entire industries and particularly in a highly interconnected and vitally important sector like energy, managing and planning for these disruptive changes may require long-term support around new industries in order for new pathways to succeed. Given the original high price of these technologies and the range of technical and market based consequences of their deployment, means that the state may have to play a crucial long-term role as coordinator and shaper of technological trajectories to manage information asymmetries and negative externalities. This entails that the energy disruption is perhaps an influencing factor in why industrial policy is widely being reconsidered in many countries around the world. This can be seen in the UK, where there are signs that the dominant non-interventionist economic logic is increasingly being challenged as industrial policy makes a return, but whether the prospects of a coming disruption in the energy sector is playing any central role in this, remains to be seen.

In Germany, it was highlighted that there are substantial fears around the loss of German industrial leadership in the face of new emerging 'disruptive' technologies particularly electric vehicles. This relates in particular to competition from China, and the notion that the German automotive sector is not adapting fast enough to the production of electric vehicles. New initiatives by BMWi and associated platforms around electromobility, as well as the explicitly stated 'modern industrial policy' could represent in part a reaction the potential disruption of the global automotive sector and German companies being left behind.

6. Conclusions

This paper has focussed on industrial policy in the energy transitions of Denmark Germany and the UK, highlighting key differences between the three countries with regards to industrial policy, and the interactions between disruption in the energy sector and industrial policy. As discussions around industrial policy gather pace, this analysis has provided insights into how the low carbon transitions of Denmark Germany and the UK entail differing characteristics of disruption, and how these energy transitions differ in terms of the role and variety of industrial policy deployed in each context. Rather than a definitive causal link between industrial policy and disruption in energy, we have identified different ways in each context through which industrial policy has enabled and hindered disruption as well as how disruptive processes in the energy sector may be influencing industrial policy responses.

The framework developed in this paper can assist in understanding the differing nature and role played by industrial policy in energy transitions, a factor that has hitherto been under researched in the broader field of energy transitions.

The research is of course limited by the particularities of each case study country, and the types of actors that were interviewed. For example, while finance is a crucial consideration of varieties of industrial policy approaches, these actors were unavailable to be interviewed during this research process and so this issue was not discussed. Opening up future research on this topic to a wider variety of actors would be an important step, given the greater diversity of actors that operate in the broad field of energy policy, some of which were not included in this study.

Nevertheless, the analytical framework offers an approach for future research in different energy contexts to garner further insights on the interactions between disruption and industrial policy. The propositions discussed in the last section of this paper, offer a starting point in building insights into what the relationship between industrial policy and disruption may be, forming the basis of future investigation in other countries. Given that a return of industrial policy is evident in many countries, and disruption is a keyword increasingly being discussed in energy policy circles, it is important to gather more empirical evidence to enhance understandings of how these two areas interact to inform future policymaking endeavours around low carbon transitions.

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