Multiple dimensions of disruption, energy transitions and industrial policy

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Abstract

In this perspective article, we critically explore 'disruption' in relation to sustainability transitions in the energy sector. Recognising significant ambiguity associated with the term, we seek to answer the question: What use has 'disruption' for understanding and promoting change towards low carbon energy futures. First, we outline that different understandings and dimensions of 'system disruption' exist with different linkages to institutional and policy change. This variety points out a need to research in more detail the particular effects of differing low-carbon innovations in terms of their disruptive consequences for whole socio-technical systems. Thus, disruption can be utilised as a useful conceptual tool for interrogating in more detail the ways in which energy systems are changing in particular contexts. Second, we reflect on the relationship between 'green industrial policy' and disruption. In some contexts 'energy disruption' has been facilitated by green industrial policy, and it would seem that the profound changes said to be on the horizon in terms of disruption are also a motivator of green industrial policy. New industrial policy can be an important way in which the negative consequences of disruptive change, such as job losses, can be managed and facilitated.

1. The 'Disruption' of everything: just another buzzword?

Discussions of 'disruption' have gained increasing traction in policy (European Commission, 2014; Innovate UK, 2017) and academia (e.g Nagy et al., 2015; Sioshani, 2017) alike. The term 'disruptive technology' was initially coined in 1995 (Bower and Christensen, 1995; Christensen and Rosenbloom, 1995) and mainly used in the subsequent years to discuss the renewal of firms in the context of business and organisational studies. However, recently the term has become more prolific than ever, spurred on by apparent momentous changes in a range of sectors. These often interconnected developments include automation in transport, 3D printing, digitalisation, the 'gig economy' and 'smart' energy. Definitions have been used further afield to discuss changes in education and health care (Horn and Staker, 2015; Hwang and Christensen, 2008). In an important online article for the *New Yorker,* Lepore (2014) cynically observed that today *"everyone is either disrupting or being disrupted"* and argued that *"every era has a theory of rising and falling, of growth and decay…our era has disruption"*. The ubiquity of the term is seen by many as being problematic, with suggestions that the theory of disruption may be *"dead wrong"* (Kitroeff, 2015) due to its vagueness and lack of definitional clarity, and that it is time to *"retire"* disruption, *"Silicon valley's emptiest buzzword"* (Alexander, 2016). King and Baatartogtokh, (2015) inquire 'how useful is a theory of disruption'?

Indeed, with the ubiquity of the term, there is a danger that surrounds many popular academic 'buzzwords', e.g. the nexus (Cairns and Krzywoszynska, 2016), in that the meaning is often vague or multiple interpretations exist, while simultaneously the term is employed in a normative way to justify a variety of disparate policy actions. Given the increasing use of the term disruption in (energy) policy, it is vital to ascertain how policy actors understand disruptive processes. A nature editorial on the subject of academic buzzwords cautions: *"choose your buzzwords carefully"* (Nature, 2016). With this in mind, we outline our perspective on disruption – highlighting that important dimensions exist worthy of further empirical interrogation of use for energy studies. Before we do so, we first briefly

discuss the term disruptive innovation highlighting some definitional issues and debates in Section 2. We move to discuss in Section 3 the importance of considering systemic understandings of disruption in the energy sector. In Section 4, we present the important role of green industrial policy in managing systemic disruptive effects of low carbon transitions, hitherto under-acknowledged in the literature. Section 5 concludes.

2. Origins and critiques of 'disruptive innovation'

Before discussing disruption in relation to energy, it is worth recapping briefly on some of the key points of discussion regarding disruptive innovation. The term emerged with the observation that incumbent firms had been incapable of 'catching the wave' of innovative technological developments due to their continued investment in products which suit existing customers rather than anticipating the emergence of new markets and investing in them (Bower and Christensen, 1995). Specific technological advances in which incumbent firms failed to respond adequately to keep their competitive advantage abounded in the 1990s, including the rise of Walmart, the difficulties facing Goodyear in terms of radial tire designs, Xerox missing out as Canon took over the small copier market, and Bucyrus-Eire losing trade as Caterpillar took over the excavator market (Bower and Christensen, 1996).

The two crucial distinctions outlined by Christensen (1997: xix) are between *'sustaining'* and *'disruptive'* technologies: "*some sustaining technologies can be discontinuous or radical in character, while others are of an incremental nature. What all sustaining technologies have in common is that they improve the performance of established products, along the dimensions of performance that mainstream customers in major markets have always valued."* Disruptive technologies on the other hand, are defined as those that "*bring to the market a very different value proposition than has been available previously. Generally, disruptive technologies under-perform established products in mainstream markets. But they have other features that a few fringe (and generally new) customers value*" (Christensen, 1997: xix). The only solution, argued Christensen (1997), for incumbent firms to 'confront' disruption was to create a separate autonomous unit within their firm to align and create a business model around a particular disruption. The theory was updated by Christensen and Raynor (2003) to 'disruptive innovation' with the recognition that fundamental changes to *business models* could also cause disruption without any fundamental technological change.

Since then a number of critiques have been raised. Chesbrough (2001) argued that analyses of disruptive innovation, and anticipating and predicting the effects of disruptive innovations, were problematic (1) due to the lack of precise and consistent terminology and (2) due to causal explanations being based on the particularities of a unique context and mainly from the USA. Another key critique was that the disruptive technology framework used past selective examples to suit a particular theory or 'cherry picked' examples and, while it was useful in identifying *ex post* disruptive innovations, could it identify disruptive innovations *ex ante* (Danneels, 2004)? This has led to the development of frameworks to 'anticipate' disruptive innovations (Paap and Katz, 2004), and to forecast the diffusion of disruptive innovations (Linton, 2002). However, a lack of 'empirical clarity' between what constitutes a 'technological' disruption as opposed to a 'business model' disruption makes accurate assessments and predictions of disruption complicated (Markides, 2006). Christensen has responded to some of the critique in an ongoing process of clarifying the theory of disruption (Christensen, 2006; Christensen et al., 2015). The issues of ambiguity surrounding the term relate, however, partly to the fact that the concept has expanded into areas, such as health and social care (Christensen et al., 2006) that operate in fundamentally different ways than the American-based start-ups and incumbent companies. The new contexts to which the terms 'disruptive innovation' or

'disruption' are being applied, including health and social care, education, mobility and energy provision entail more socio-technical than firm-based characteristics, including values that extend from market performance and technological efficiency to public goods provision, welfare, social equity and environmental sustainability. Thus, from a socio-technical system perspective, 'disruption' benefits from new insights.

3. The energy 'disruption': what's the added value?

We argue that 'disruption' is an important conceptual tool for analysing the ways in which socio-technical (energy) systems are changing in particular contexts. This means that rather than a mere focus on firms and technologies, it is useful to analyse system change in terms of what dimensions of the system have been or are being disrupted – or need disruption to reach a more environmentally and socially sustainable society. We have elsewhere proposed that disruption can extend beyond technology to, at least, the following dimensions of socio-technical systems: the composition of actors and networks, market structures, dominant forms of business models, the division of ownership between different actors, and regulations and other institutional settings (Johnstone et al., 2017). This implies that from a socio-technical system perspective, disruption portrays differently depending on whether only one or more of the dominant forms of dimensions have been disrupted.

Disruption in actors and networks implies a shift in the power positions of actors, such as reduced importance of incumbent utilities, or significant changes in the key networks in the dominant socio-technical system, including the entry of new actors. Disruption in market structures may, for example, involve a significant change in the institutional logics (Fuenfschilling and Truffer, 2014) and a visible shift in consumer preferences (Dijk et al., 2016). Disruption in business models relate to how value is captured from technologies or services and who the key actors are delivering such value. For example, energy sector business models are changing from simply the provision of energy and heat by large utilities towards bundling of energy services to consumers, e.g., around smart homes (Midttun and Piccini, 2017) and community solar provider models (Burger and Luke, 2017). Such community ownership and consumers' participation in the provision of electricity and heat (prosumers) are examples of how new business models also link to altered ownership structures. Finally, disruption of institutions geared around the old dominant socio-technical system (Fuenfschilling and Truffer, 2014) means, for example, the removal of subsidy schemes supporting old technology (Kivimaa and Kern, 2016) and the introduction of regulatory frameworks that allow new, potentially disruptive inventions to develop into widespread innovations.

Many renewable energy technologies are considered disruptive, because they are provoking significant changes in the grid, business models and regulation simultaneously. This relates to a fundamental shift away from centralised grids with large production units and passive consumers to more decentralised forms of energy production and novel business models involving communities and citizens as active participants. Yet, at the same time, incumbent energy system actors are fighting back, for example, by large utilities buying up independent wind power developers to eliminate competition in the UK (Negro et al., 2012) or engaging in shaping emerging technological fields by creating more centralised models (e.g. offering centrally located solar panels to the ownership of utility customers) to produce and sell renewable electricity in Finland (Apajalahti et al., 2017). This means that many incumbent utilities frame themselves as proponents of renewable energy, while simultaneously safeguarding the centralised utility model. Countries differ and, while disruption is seen to be well under way in Germany and Denmark – not only through a larger share of renewable energy but also through changed actor positions, more decentralised business models and ownership

structures, and changed regulation – in countries, such as Finland and the United Kingdom (UK), more centralised systems are still in place. Yet, plummeting wholesale electricity prices seen across Europe are affecting the revenue streams of leading utilities, where conventional power plants are being priced off the market (The Economist, 2013a). These changes are dramatic in countries, such as Germany, where much renewable capacity is owned not by the utilities but by community energy groups and cooperatives.

The effects of the growth of renewable generation on existing energy utilities across Europe are clear. What is less clear is how energy system disruption is occurring in different European countries and what the differences are in the ways in which disruption happens. For example, renewable energy has already gained a rather significant share of electricity production in many countries, effectively disrupting the fossil-fuel based market and business models that have long been in the hands of large utility companies. However, the implications of this change to the energy system differ radically depending on whether merely fuel sources have changed or also ownership models and regulatory structures have disrupted as well. The latter – as is evidenced in Germany and Denmark – have larger consequences, for example, for energy justice (through increased ownership of production by citizens), grid infrastructure (through increased small-scale distributed generation) and employment (through what type of companies/cooperatives employ people).

Looking more closely at Germany, Denmark and the UK, differing aspects of systemic disruption can be observed (illustrated in Table 1), indicating that the nature of disruption differs based on context and that there is no centralised model for 'clean disruption'. According to a Silicon Valley-based entrepreneur and author Tony Seba, who talks about clean energy disruption, new technological developments, including an increased use of solar energy, storage technologies and ICT, will fundamentally alter the 'energy architecture' of our lives, moving away from a resource-based (coal, gas, and uranium) system to an information-based one, the latter being fundamentally different and based on "zero marginal costs". While "*the energy and transportation industries have a business model similar to Kodak's in that every time you flick a switch you pay a utility and flicking a switch requires additional costs in terms of resource extraction,* new renewable energy technologies change the equation because "*after you build a solar rooftop installation, the marginal cost of each additional unit of energy drops essentially to zero because the sun and the wind are free*" (Seba 2014: 4). While his vision is more global and does not account for the context specificity we outline in Table 1, Seba does contend that also utility scale renewables are already disrupting the wholesale electricity market.

Table 1: Aspects of energy system change in Denmark, Germany and UK

	Denmark	Germany	UK
Technology	Increasing penetration of wind power	Large growth in wind and also PV since 2000	Dominance of offshore wind; support for solar, onshore wind reduced or removed in 2015
Grid	Effects on the load balance of the grid	Problems of surplus solar generation; leading to rises in grid frequency through rotating load	Issues around changes in voltage and grid frequency
Actors & networks	New actors, e.g. "heavily active, responsive and reflexive consumer" (Karnøe and Garud, 2012; p.77)	Key role for community energy groups and consumer-led solar production with 41% of the 8GW of solar operated by individuals selling back to the grid	Incumbent actors dominate and new actors do not have a significant role. Limited role for consumers at present as acknowledged by OFGEM (2017)

Market structures	Early intervention; subsidies for wind technology manufacturers and production and early 'technology specific' Feed-in-Tariff's from the 1990s	Early 'technology specific' intervention for wind. EEG and feed-in-tariff's established in 2000	Market oriented; non-technology specific support including. Non-fossil-fuels obligation and renewables obligation. Technology specific feed-in-tariffs introduced in 2010
Business models	Changes in business models, e.g. DONG's climate partnerships offering consultancy and project management services around energy demand reduction	Changes in business models, e.g. community-owned solar and utilities searching for more service oriented consumer-led business models	Major utility business models dominate. Lack of focus on service and consumer-driven business models as identified by OFGEM (2017)
Ownership	Cooperative ownership models; over 100,000 people in wind cooperatives; 30% community benefit for large renewable projects.	Half of renewable energy is citizen owned; majority of small and medium PV units are owned by private individuals (41.8%), farmers (22.5%) and SMEs (20.3%) –utilities have lost 97% of the PV electricity generation market	Renewable energy assets mainly owned by existing utilities; less than 15% of renewable capacity is citizen owned; 5% community benefit for large renewable projects
Regulation	Paradigm shift in pricing and regulation to properly value wind. Integration of power and heat.	Changes in rights and obligations of consumers and prosumers in the electricity sector to sell back electricity to grid	Problems of lack of regulation of household solar. Current changes being made to enable consumers to sell back to the grid
Sources	Balch, 2015; IRENA, 2012; Karnøe and Garud, 2012; Karnøe and Karne, 2017	Grigoleit and Lenkeit, 2011; Morris and Jungjohann, 2016; Richter, 2013a; Strunz et al., 2015	Mitchell et al., 2016; Nolden, 2013; OFGEM, 2017; Seyfang and Haxeltine, 2012

We argue that at the level of socio-technical systems, disruption can be understood as an interplay between technological and institutional change. On the one hand, the advances in potentially disruptive ICT, storage and renewable energy technologies have created a need for institutional changes – comprising both informal practices and formal regulatory institutions. On the other hand, institutional changes that can be seen as disruptive to centralised large-scale energy systems, for example, allowing grid connection with reasonable costs to small distributed energy production and facilitating new ownership models, in turn support new disruptive innovations in energy to emerge.

We will below discuss one specific example of institutional change – the emergence of green industrial policy – and its potential influence on energy disruption. While green industrial policy and systemic disruption may not seem obviously connected, we show below how industrial policy as an institution has been relevant both in sustaining and disrupting the dominant values of the energy system. This is of interest to us due, first, to the return of political interest in industrial policy and, second, the implications of energy disruption not merely to incumbent business models or the grid but to the restructuring of industries and employment.

4. How does green industrial policy link to energy disruption?

Traditional 'industrial policy' is a term that for many, belongs to a different era to the current disruptive one. This refers to interventions, where states have played a key 'top down' role in enhancing the competitiveness of existing industries – deemed important for the country in question – through a range of long-term policy support mechanisms including subsidies, export policies, and strategic investment in skills and training to direct industry (Bianchi and Labory, 2006). In the late 1980s, as neoliberalism swept across the USA and parts of Europe, industrial policy was a term that fell out of favour. Instead, it was expected that relying on markets with minimal state intervention was the best way of coordinating industrial activities.

Nevertheless, industrial policy continued to be important in countries relying for a large part of their GDP in large exporting industries. For example, in Finland, the pulp and paper industry dominated energy policy making for decades until, during the last decade, its importance reduced mostly due to declining world paper markets (Kivimaa and Mickwitz, 2011). While not necessarily explicitly recognised as industrial policy, in Germany, the provision of long-term finance through national investment banks and local banks, the close collaboration of business, finance and trade unions in long-term decision making on industry, and the long-term investment in publically funded vocational training and export platforms coordinated by the state, can be interpreted as an implicit form of industrial policy (Johnstone et al. 2017; Ćetković and Buzogány, 2016; Hancké and Coulter, 2013). Certainly Germany is recognised as having 'industrial policy' from the perspective of countries like the UK (Elliot, 2016). Also, many other European countries still favour tax exemptions or other support mechanisms for energy intensive industry.

Even in countries that have been averse to notions of industrial policy, following the financial crisis of 2008 and issues surrounding productivity and jobs, there has been a 'return' of the concept (Ciuriak, 2011; Ciuriak and Curtis, 2013; Stiglitz et al., 2013). One such example are the UK plans for new industrial strategy. But how does this trend relate to energy disruption? Well, for one, the UK Green Paper on Industrial Strategy (BEIS, 2017) relates to the technological aspect of energy disruption, outlining energy storage, demand response grid technologies as potential strategic funding options and coordinating changes to the energy infrastructure triggered by new technologies.

Understanding the relationship between disruption in the energy system and industrial policy has been one of the areas of research undertaken as part of the *Smart Energy Transition* project, and discussed in work comparing disruption and industrial policy in Denmark, Germany and the UK (Johnstone et al. 2017). For a start, it is important to recognise that discussions around industrial policy are focussed on broadening the understandings of industrial policy, away from the notion of 'picking winners' and top down approaches to support existing industries, towards 'new' industrial policy that is focussed on supporting the creation and promotion of new industrial trajectories (Bianchi and Labory, 2006; Dhéret et al., 2014; Stiglitz et al., 2013). One key area in which future growth opportunities are thought to lie is the green economy, and the potential for green industrial policy combining the creation of new growth and export opportunities for particular countries with environmental goals such as Climate Change mitigation (Hallegatte and Vogt-schilb, 2013; Rodrik, 2014). Green industrial policy is defined by Pegels (2014: 5) as "government intervention to hasten the restructuring of the economy towards environmental sustainability". However, this definition is broad, and we argue there are more nuanced ways of understanding industrial policy stemming from recent literatures.

Recent research highlights 'varieties' of industrial policy (Andreoni, 2017), and the 'matrix' approach to understanding industrial policy (Aiginger and Sieber, 2006; O'Sullivan et al., 2013), which include

different elements from the role of trade unions and manufacturing policies to comparisons of regional and national dimensions. In addition, long-term visions, stable policies and 'mission oriented' approaches to hastening the direction of industry towards new green technological trajectories have been highlighted as important (Mazzucato, 2015; Mazzucato et al., 2015). Thus, implementing a new 'green' industrial vision, in particular when it replaces 'old' industrial policy, would be an institutional change that can support, or even be part of energy disruption. In practice, following the example of Denmark – including a directed reorientation of jobs from fossil to renewable energy industries (Engel et al., 2009) – this would mean rethinking the allocation of subsidies and educational focus areas as well as create a strategy for redirecting and retraining people employed by the energy sector. Indeed, subsequently Denmark has become one of the leading countries in energy technology export (Danish Wind Industry Association, 2017), showing a coupling between green industrial policy and domestic sustainable energy disruption.

As we noted above, Denmark and Germany are two countries where energy disruption is thought to have advanced the most (Karnøe and Vol, 2012; Quitzow et al., 2016). This is emphasised by the decentralisation of energy production and partly changed grid infrastructure but also by the destabilisation of incumbent business models coupled with new forms of ownership and production. In Germany, traditional utility companies have been severely damaged by the changes that have taken place over the past thirty years and are having to radically alter their business models as a consequence (Richter, 2013b; Wainstein and Bumpus, 2015). The big four utilities own less than 60% of conventional power supply (Clean Energy Wire, 2015) and only 7 % of renewables capacity (The Economist, 2013b).The UK, on the other hand, while increasing the proportion of renewables capacity in recent years, still operates around a centralised paradigm of energy production, the main incumbent utility companies controlling 85% of the energy market (Johnstone et al. 2017; Mitchell et al., 2016). For many energy policy stakeholders, the UK represents a low carbon transition without multidimensional disruption (through processes of decentralisation and changing business models) taking place (Johnstone et al., 2017).

We argue that, while in some sectors disruption may be primarily a consequence of competition between businesses at the firm-level, when it comes to energy disruption, there is a key role for institutional change, for example through green industrial policy, in facilitating socially and environmentally sustainable energy disruption. As yet, this connection has not been sufficiently explored. Discussions on the 'clean disruption' in the language of Silicon Valley, neglect processes of sustainability. Yet, importantly, a focus on both disruption and industrial policy, emphasises that both environmental sustainability and social sustainability should be sought in energy transitions. While in such transitions, some will inevitably come out as winners and others as losers, a sustainable energy transition should consider a sustainable redirection of jobs – pointing to the importance of green industrial policy as a supportive institutional change.

Thinking again about the systemic nature of disruption, in energy systems perhaps more so than in other systems – given the immense sunk costs and the fact that it connects so importantly to the overall economy – disruption is not only a matter of established firms being disrupted by start-ups. Rather energy disruption entails much broader disruption in terms of the structure of the economy, particularly around substantial declines in traditional industries that supported long-term jobs and community livelihoods. Thus, related to this, green industrial policy should include a long-term vision around new economic opportunities for sustainable manufacturing and service sectors, where the state plays an important role in coordinating initiatives around the reskilling and diversification of existing fossil-based employment towards the green economy.

Returning to the definitional fuzziness raised at the beginning of this piece, while 'disruption' is often used in a normative sense as a positive development in the world of business and Silicon Valley (Alexander, 2016), for parts of society these processes imply significant losses and negative disruption, highlighting the importance of a clear strategy around planning for new industrial futures as part of the green economy. As in Denmark and to a lesser extent Germany, policies aimed at lessening the impact of the decline of fossil fuels through long-term governmental support for industry as green industrial policy seems to have been a critical yet overlooked factor in facilitating disruption in the energy system (Johnstone et al. 2017). The social effects of rapid departures from fossil fuel based economic activity without green industrial policy and relying more on the market rather than state as coordinator of employment opportunities is highlighted by the lasting poverty, and social issues still in existence in former coal mining regions of the UK (Foden et al., 2014; Johnstone and Hielscher, 2017). Thus, green industrial policy can be important in managing the negative social sustainability consequences of the energy disruption. Such an approach may also reduce barriers to accelerated energy disruption, for example, by engaging trade unions and trade associations into a thorough discussion on the redirection of employment. Often trade unions resist transitions away from fossil fuels due to the issue of potential job losses associated with disruption (Lütkenhorst and Pegels, 2014).

5. Conclusion

In this perspective article, we discussed the notions of disruption in connection to institutional change briefly and industrial policy more specifically, highlighting definitional issues and inconsistencies which make this term potentially problematic. However, in advocating a more systemic rather than firm-based perspective on disruption, we argue that disruption can offer a useful way of engaging in more empirically-driven work to understand the differing ways that business models, ownership, actors and networks, policies, and technical and social aspects are implicated in energy transitions. Moreover, the interplay between technological and institutional factors seems to be important in energy disruption, but has received little specific attention and conceptual development.

After pointing out the kinds of disruptive changes that are occurring in energy systems, we focussed on the under-studied role that 'green industrial policy' has played in studies of 'disruption'. In general, energy systems in Western countries range from those with recent significant influence from traditional industrial policy typically safeguarding the price and availability of energy to energy-intensive industry, to those having embraced green industrial policy (implicitly or explicitly) with implications on both reducing the fossil-fuel reliance of domestic energy production and creating new export industries in sustainable energy. In the latter, long-term visions and a culture of citizen and community involvement have played an important role; in the best cases the state has played a coordination role in reskilling and diversification of employees. Regarding the latter, we highlighted the opportunity to direct disruption not only towards more environmentally sustainable but also towards more socially sustainable direction. Thus, in terms of jobs and economic prospects, new industrial policy can be an important way in which the negative consequences of disruptive change can be to a degree managed and facilitated. Future research could usefully explore further the relationship between emerging green industrial policies and energy disruption.

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