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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 [1,2] and academia (e.g [3,4]) alike. The term 'disruptive technology' was initially coined in 1995 [5,6] 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 [7,8]. In an important online article for the *New Yorker,* Lepore [9] 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"* [10] due to its vagueness and lack of definitional clarity, and that it is time to *"retire"* disruption, *"Silicon valley's emptiest buzzword"* [11]. King and Baatartogtokh [12] 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 [13], 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"* [14]. 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 certain incumbent firms had been incapable of 'catching the wave' of

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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 [5]. 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 [15].

The two crucial distinctions outlined by Christensen () 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*" (). The only solution, argued Christensen [16], 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 [17] to 'disruptive innovation' with the recognition that fundamental changes to *business models* could also cause disruption without any fundamental technological change.

Since Christensen a number of critiques have been raised. Chesbrough [18] 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, it was uncertain whether it could identify disruptive innovations *ex ante* [19]?. This has led to the development of frameworks to 'anticipate' disruptive innovations [20], and to forecast the diffusion of disruptive innovations [21]. 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 [22]. Christensen has responded to some of the critique in an ongoing process of clarifying the theory of disruption [23,24]. 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 [25] 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 potentially require 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 [26]. 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 [27] and a visible shift in consumer preferences [28]. 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 [29] and community solar provider models [30]. Such community ownership and consumers' participation in the provision of electricity and heat (i.e. 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 [27] means, for example, the removal of subsidy schemes supporting old technologies [73] 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 [31] 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 [32]. 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 [33]. These changes are dramatic in countries, such as Germany, where much renewable energy 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).