**Disruption and continuity in energy systems: evidence and policy implications**

**Special issue of Energy Policy**

**Editorial**

Ioanna Ketsopoulou, UKERC and UCL Institute for Sustainable Resources

Peter Taylor, University of Leeds

Jim Watson, UCL Institute of Sustainable Resources and UKERC

Revised following review, 3rd September 2020

## Introduction

Energy systems around the world are changing fast due to rapid technical change, the need to tackle climate change and growth in demand in the developing world. The Paris Agreement and the IPCC's 1.5 degree report have strengthened the case for rapid emissions reduction – including plans to transition to net zero energy systems and economies by mid-century. A key feature of this emerging revolution is the disruption of established technologies, markets and business models.

The pace of change is particularly pronounced in electricity, where the costs of some renewable energy technologies have fallen dramatically. The prospect of cheaper electricity storage plus the application of information communication technologies has recast expectations about sustainability, costs and security. Electric vehicles are also being adopted in increasing numbers in many countries. However, potential disruptive change is not confined only to low carbon technologies as the shale gas revolution in the United States has demonstrated. Furthermore, the global coronavirus pandemic shows that disruptions to energy systems could also be caused by external shocks.

This Special Issue comprises six papers that present the findings from a major research project on energy system change conducted by the UK Energy Research Centre. This project explored a spectrum of energy system change. At one end of this spectrum is gradual or 'continuity-based' change which takes place in line with existing trends. Disruptive change is at the other end of the spectrum, and involves significant deviations from past trends in a short space of time. Disruptive change can also be defined by the magnitude of its impact on existing actors – particularly the companies that own, operate or manufacture energy infrastructures and technologies.

The Special Issue brings together a range of evidence from the UK to answer three questions:

1. What are the potential sources of disruption to energy systems?

2. Which sectors and actors might face particularly disruptive change?

3. How should governments and other decision-makers respond to ensure that the low carbon transition is implemented successfully?

In addition to answering these questions, the Special Issue also makes a contribution to the literature on energy system change – particularly the sources and impacts of disruptive or discontinuous change.  As this literature shows, disruption can affect energy systems in a number of ways, e.g. disruptions due to changes in politics, in technology development, institutional arrangements, or disruption to established business models and value networks. The potential extent of energy system disruption has been widely debated (Winskel, 2018; Mitchell, 2016; Johnstone and Kivimaa, 2018)

Much of the previous literature on disruption has focused at the firm level. The term 'disruptive innovation' first gained popularity through Christensen's book *The Innovators Dilemma* (Christensen, 1997) and has since been applied to many different sectors. More recently Christensen et al (2015) claimed that the term has often been misinterpreted and misused and clarified that 'disruption' only occurs when an already established player in an industry is successfully challenged by a newcomer. Criticism has been expressed regarding the *ex ante* applicability of his approach, the criteria he uses to make a distinction between incumbent firms and new entrants and how he classifies firms as successes or failures (Lepore, 2014). Christensen's theory of disruptive innovation has also been criticised regarding its applicability and relevance to low carbon transitions (Geels, 2018; McDowall, 2018; Wilson; 2018).

Another branch of the literature explores disruption in sociotechnical systems. Unruh (2000) introduces the concept of a 'techno-institutional complex' to demonstrate how modern economies are locked into the use of fossil fuels by increasing path dependency and institutional and technological returns to scale. Geels (2011) argues that sustainability transitions in particular are characterised by substantial differences compared to other types of transition, which have typically emerged in a more organic manner.

Unruh (2002) also argues that technological and institutional influences exogenous to the current system will be required in order to overcome lock-in and offers a classification of generic policy approaches that can be followed to achieve this: *end-of-pipe*, where only the resulting emissions are treated; *continuity*, where selected components of the system are modified but the overall architecture remains unchanged; and *disruption*, where the whole system is transformed or replaced.

Recent empirical studies highlight the multi-dimensional and systemic nature of energy system change, as well as the potentially varied and context-dependent roles of different actors. In their comparison of power sector transitions in Germany and the UK, Geels et al (2016) show that under certain conditions incumbent actors can facilitate and lead low-carbon transitions. Johnstone and Kivimaa (2018) highlight the interplay between technology and the institutional aspects of disruption in the energy sector, and show how green industrial policy can direct and help manage disruption.

The UKERC project developed a simple framework to analyse energy system change, consisting of a 2 x 2 matrix (Figure 1). This was used to ensure that the research teams focusing on different sectors and issues used a common set of concepts. The horizontal axis of the matrix includes the spectrum of change discussed earlier: from continuous change to disruptive change. The vertical axis characterises the source of energy system change. This is taken from a typology developed by Smith et al (2005), and focuses on the level of coordination involved. At the bottom, there is *purposive* change that is coherently orchestrated and is aiming in a specific direction or to achieve a distinct goal. This would include policy-driven change or change via social movements, such as the environmental movement in Germany (Jacobsson and Lauber, 2006; Laird and Stefes, 2009). At the top, there is *emergent* change which is not co-ordinated, and is the outcome of a complex and diverse set of drivers, actors and decisions. Four types of change can be distinguished when these axes are combined:

- Emergent continuity: where change is continuity-based and uncoordinated. This type of change is closest to a business-as-usual scenario in terms of economic and technological development, societal norms and structures. Incumbent actors continue to influence the energy system.
- Emergent disruption: where change is disruption-based and uncoordinated. There is likely to be significant disruption to incumbent technologies, companies, infrastructures and/or policy priorities.
- Purposive continuity: where change is continuity-based and coordinated. This type of change tends to be characterised by active support for incumbent players, technologies or infrastructures – for example through 'end-of-pipe' solutions to environmental pollution.
- Purposive disruption: where change is disruption-based and coordinated. In this case, there is likely to be active disruption to incumbent firms, technologies and infrastructures – and support for new firms and innovation.

In practice, changes to energy systems are unlikely to fit neatly into one quadrant of this framework. Climate change policies seek purposive change, but could lead to a combination of disruptive and continuity-based changes. For example, as Brand et al argue in this special issue, a policy of phasing out conventional vehicles could be disruptive for electricity grid operators and finance ministries. However, this could also mean continuity for citizens who use cars as their main mode of transport.

## Six Perspectives on Disruption and Continuity

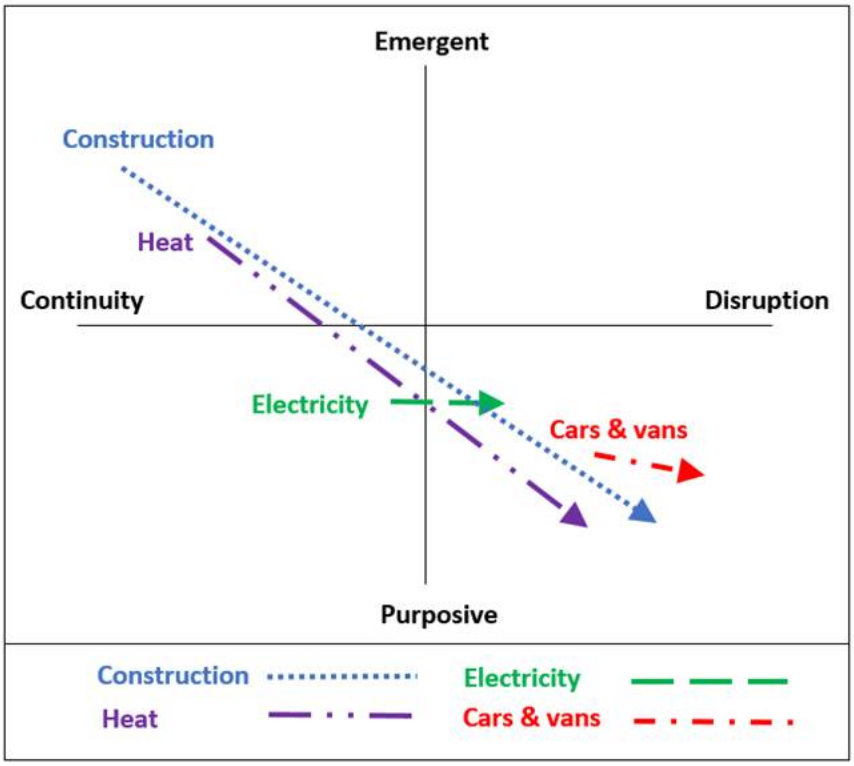
The six main papers in the Special Issue concentrate on different aspects of disruption and continuity. Most of the papers use the UK as a case study, and include policy implications that could be applicable to other countries. The first paper by Winskel and Kattirtzi analyses expert views on the UK's energy system transformation, and the extent to which they expect disruptive change. The next four papers focus in more detail on the potential role and impact of disruption in specific sectors: power, construction, heating and road transport. Figure 1 locates these four sectors on the 2 x 2 matrix developed for the UKERC project. Based on the analysis in these papers, it illustrates how their positions may need to change if the UK's climate targets are to be met.

- Electricity. A rapid shift towards low carbon electricity generation has been driven by a mixture of policy support and falling costs. This trend will continue to some extent without strengthened policies. As the proportion of variable renewables increases, further disruption will be caused to the sector which will require stronger policy incentives to increase system flexibility.
- Heat. Currently gas boilers are still being installed as the preferred heating option in most homes, with limited policies aimed at encouraging other technologies. Further strong policy action will be needed to promote low carbon heating technologies, whether this be heat pumps or hydrogen. Both of these options will cause significant disruption to many actors.
- Road transport (cars and vans). Some policies are in place to encourage electric vehicles, plus a phase out of petrol and diesel vehicles by 2035. Some strengthening of these policies will be needed (e.g. bring phase out date earlier). As the share of electric vehicles grows, the level of disruption for some actors will increase (e.g. falling revenues to government and oil companies; increased impacts on electricity networks).
- Construction. Building regulations currently determine the energy performance of new buildings, plus some information provided on energy efficiency of existing buildings. Much

stronger policies will be needed to reduce energy consumption of buildings and this is likely to require significant, disruptive changes to practices in the construction sector.

The sixth paper uses a systematic review of international literature to understand the extent to which energy systems modelling and scenario methods have been used to analyse disruptive change.

**Figure 1. A framework for analysing energy system change, with examples from the UK**




**Notes:** For each sector, the arrow starts at the current position, taking into account policies in place at the time of writing. The direction of each arrow indicates changes that could be required to meet net-zero emissions target

In their paper, Winskel and Kattirtzi set out expert views on the UK's energy system transformation over the next two decades. They present the findings of a Policy Delphi survey (n=113) on energy researchers' and senior energy stakeholders' views on whether continuity-based or disruptive change is more likely, and set out how change can manifest in different areas of the energy system. The survey focuses on governance, security and flexibility arrangements, power sector decarbonisation, the future role of incumbent supply firms and policy priorities. The survey highlights how smart energy and increased localisation is expected to gain traction over the next two decades. However at the same time expert energy stakeholders do not anticipate this shift to lead to whole system transformation. On the contrary they see in parallel development and partial repurposing of existing infrastructure and governance arrangements, and a continued role for centralised infrastructure and incumbent actors. Drawing from the survey results the authors argue that the transition is unlikely to be solely disruptive or continuity-based, but will most likely include both disruptive and continuous elements. They conclude that there is a need to open up systemic change narratives, and to follow a more nuanced issue-by-issue approach instead of an overarching narrative fixed towards either disruption or continuity-led change.

The paper by Kattirtzi et al. examines how the incumbent “Big Six” electricity utilities in the UK have responded to the potentially disruptive challenges of decarbonisation, decentralisation and digitalisation over the period from 2008 to 2018. Overall the picture that emerges is one of a gradual response, rather than any radical impact, with decarbonisation as the biggest driver. Collectively the carbon intensity of the “Big Six” generation portfolios has declined substantially, with particularly significant falls seen in coal-fired plant capacity. However, more detailed analyses of individual company shows wide variations in terms of how their generation portfolios have evolved with respect to gas, renewables and nuclear power. The paper finds much less evidence of a significant shift towards a decentralised generation portfolio, as even the new renewable investments have tended to be in large-scale hydro and wind. The impact of digitalisation on the retail market also reveals a mixed picture and, despite the gradual roll-out of smart meters and the companies themselves identifying this as a key trend, the impact on their businesses appears to have been limited. Overall the paper concludes that, during the period studied, the Big Six responded to a complex set of international and national drivers, with their response shaped by a combination of their existing electricity generation assets, the specifics of UK climate policy and the strategies of their parent companies, which for two-thirds were based outside the UK. This highlights that, in seeking to understand how incumbents will respond to change, policy makers need to take account of their international reach.

Killip and Owen focus on the role of the construction industry in reducing energy demand and emissions from existing housing in the UK. They note that achieving a transformation of the housing stock in the UK is a construction challenge as well as an energy policy challenge. Their paper uses an analytical framework to assess practices in the mainstream building repair, maintenance and improvement sector. The framework is also used to compare the mainstream sector with pioneering firms that specialise in building retrofits – and to identify similarities and differences. They conclude that the mainstream construction industry needs to change significantly if the desired emissions reductions are to be delivered. They argue that some of the required changes will be disruptive, for example to change what they call the ‘low skills equilibrium’ in the sector. In addition to significant improvements to skills, this will require better co-ordination between firms and a greater focus on formal training and learning-by-doing. The paper also emphasises a strong role for policy, including the greater use of standards in public procurement, stronger enforcement of regulations for buildings and a much closer alignment between industrial policy and energy policy.

Lowes and Woodman analyse the perceptions of policy makers about the decarbonisation of heating in the UK – and how these perceptions could impact on the policy changes that may be required. They note that heat decarbonisation is an important global challenge since heat is currently responsible for around 40% of energy-related carbon emissions. Furthermore, it is an area where little progress is being made in some countries, including the UK. The paper draws on the literature on policy processes and policy maker perceptions, and applies them using semi-structured interviews with policy actors. Based on these interviews, Lowes and Woodman conclude that policy makers in the UK perceive heat decarbonisation as being disruptive, and characterised by high costs and significant technological uncertainty. They also argue that the lack of progress with heat policy is partly due to a perception that there is a lack of evidence about which technical options are likely to be the most cost effective and least disruptive for citizens. They conclude with three recommendations for policy makers, some of which could also be applicable to other countries: first, reduce uncertainty, for example through technological trials; second, make initial progress through low regrets options such as energy efficiency; and third, accept uncertainty and implement more adaptive approaches to policy implementation.

Brand et al analyse the UK government policy of phasing out the sale of conventional petrol and diesel cars, and the implications of implementing it more quickly and extending the scope. At the time of writing, this phase out was due to be completed by 2040. The authors conclude that as originally formulated, the phase out would merely reinforce current trends and would be unlikely to cause major disruption to key actors in the transport system nor indeed help meet the Paris climate goals. They therefore argue that there is a strong case for bringing the date forward to 2030 and including hybrids in the phase out. Even this earlier date would not cause major long-term disruption to consumers and wider society, who would still have access to vehicles that provide similar functionality to today once any recharging and range issues have been addressed. However, a 2030 ban would cause more significant disruption for vehicle manufacturers, global production networks, and the maintenance and repair sector. Government would also likely see disruptive effects from the loss of tax revenue on petrol and diesel sales and oil companies could face a loss of sales. However, the paper concludes that the impacts on government finances could be mitigated by either a tax on electricity for transport use or road pricing. Even oil companies may not suffer significantly if they see a growth in demand for their products from other sectors.

In the final paper in the Special Issue, Hanna and Gross explore how energy systems models and scenarios represent and assess disruptive change. The paper presents the results of a systematic evidence review of academic and grey literature. This started with a general review of energy models and scenarios to provide an overview of different approaches and their common applications. This is used as a basis for a more focused review on their use to explore disruption or discontinuity in energy systems. The results of the more focused review demonstrate that energy models and scenarios have not been used extensively for this purpose. However, it also identifies some cases where disruptive change has been explored. Hanna and Gross conclude that some methods could be more suitable for exploring disruptive change – particularly exploratory scenarios, agent-based models and formal approaches that combine quantitative models and qualitative scenarios. In conclusion, they recommend that policy makers should use a wider range of models and tools to help them understand energy system change, particularly mixed-method approaches.

## Conclusions and policy implications

Taking these papers together, what new evidence do they provide in answer to the three main questions posed at the start of this editorial?

With respect to the first question on sources of disruption, there is a lot of uncertainty. Whilst significant disruption is already affecting some parts of the energy sector, the paper by Kattirtzi and Winskel shows that shows that stakeholders have divergent views of the future – and the extent to which energy system change will be characterised by disruption or continuity. In alignment with Unruh (2002), it also suggests that further disruption is inevitable if the UK and other countries are to make successful transitions to a low carbon energy system on the timescales required by the Paris Agreement and national targets. In the UK at least, there is also a significant gap between what stakeholders expect to happen, and what they think is necessary to meet such targets.

Although many of the papers in the special issue have focused on technological change, this is not the only source of disruption. For example, shifts in political priorities have already led to ambitious climate change targets that have driven some of the disruptions so far. Reflecting Jacobsson and

Lauber (2006) and Geels et al (2016), the paper by Kattirtzi et al demonstrates that this has particularly affected the power sector. By contrast, the paper by Killip and Owen shows that the construction sector has not been affected yet – but this is likely to need to change if emissions from homes are to be reduced significantly. But, echoing Laird and Stefes (2009), this could also work the other way – wider changes in politics in the UK and other countries could undermine the case for climate action. At the time of writing, another major source of disruption is unfolding world-wide. Whilst it is too early to tell whether and how the global coronavirus pandemic will affect energy systems and plans to reduce emissions, the implications will be significant. This highlights a more general need to consider sources of disruption that come from outside the energy system, which is highlighted in the systematic review of models and scenarios in this issue by Hanna and Gross.

The answer to the second question is also conditional: disruption to energy systems will affect some actors more than others. There is some evidence of adaptation by incumbent companies, particularly within the power sector. As the paper by Kattirtzi el al shows, many of the Big Six power companies in their UK have changed their strategies in response to climate policy, new entrants and a loss of trust. This is in alignment with Jacobsson and Lauber (2006) and Geels et al (2016). In other sectors, change is at an earlier stage. For example, Killip and Owen demonstrate that disruptive change is likely to be required in the construction sector to transform the building stock and make it compatible with climate change targets. Lowes and Woodman emphasise the uncertainty about how heat decarbonisation will be achieved. This means that it remains unclear what role incumbent heating firms will play in decarbonisation, and whether they will have the capacity to do so. Some of these incumbents face starkly divergent futures – including futures where their core assets will need to be phased out. With respect to road transport, a wholesale shift to electric and other low carbon vehicles may mean continuity for many of those who own and drive cars. But Brand et al also argue that this could be very disruptive for some firms in the supply chain, for electricity network companies and for government too.

Finally, what are the lessons for policy makers in the UK and other countries? The prospect of further disruptive change represents a particular challenge for government policy. This is because the extent and impacts of some potential disruptions are inherently uncertain. As the paper by Lowes and Woodman on low carbon heat policy illustrates, this uncertainty may be compounded by an understandable reluctance to take courses of action that might be disruptive to citizens. By contrast, several papers in this Special Issue suggest that some sectors may need to be deliberately disrupted by government policies if they are to be compatible with a net zero economy. This reinforces the conclusions of previous research on sustainability transitions and disruption (Unruh, 2002, Smith et al, 2005; Johnstone and Kivimaa, 2018).

This Special Issue provides two key recommendations for decision-makers to help them deal with this uncertainty. First, as Hanna and Gross conclude, a wider range of models and tools could be used to inform energy and climate change policies. Some of the models that are currently used provide limited insights about the potential social, economic and political impacts of disruptive change. For example, energy systems modelling could be complemented by analysis of distributional implications to identify potential winners and losers. Furthermore, the current global pandemic highlights the importance of scenarios that explore the potential impacts of systemic disruptions from outside the energy sector. Second, a review of international policy experience that was carried out for the UKERC project points to the advantages of a flexible and adaptive approach to policy development and implementation (Watson et al, 2019). This approach can help governments to respond quickly to unexpected consequences, and reduce the impacts of unforeseen events.

**References**


Christensen C, Raynor M, McDonald R. (2015) What is disruptive innovation? Harvard Business Review, December 2015 [accessed 3rd February 2017]

Christensen C. (1997) The Innovator's Dilemma. When New Technologies Cause Great Firms to Fail. Harvard Business School Press. Boston, Massachusetts

Geels, F. (2011) The multi-level perspective on sustainability transitions: responses to seven criticisms. Environmental Innovation and Societal Transitions, 1, 24-40

Geels, F. (2018) Disruption and low-carbon system transformation: progresses and new challenges in sociotechnical transitions research and the Multi-Level Perspective. Energy Research & Social Sciences, 37, 224-231

Geels, F., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., Neukirch, M., Wassermann, S. (2016) The enactment of socio-technical transition pathways: a reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014), Research Policy, 45 (4), 896-913

Jacobsson, S., Lauber, V. (2006) The politics and policy of energy system transformation--explaining the German diffusion of renewable energy technology. Energy Policy, 34 (3): 256-276

Johnstone, P, Kivimaa, P. (2018) Multiple dimensions of disruption, energy transitions and industrial policy. Energy Research & Social Science, 37, 260-265

Laird, F.N., Stefes, C. (2009) The diverging paths of German and United States policies for renewable energy: Sources of difference. Energy Policy, 37 (7): 2619-2629

Lepore, J. (23 June 2014) The Disruption Machine: What the gospel of innovation gets wrong. *The New Yorker*. Available from: https://www.newyorker.com/magazine/2014/06/23/the-disruption-machine [accessed 6th August 2020]

McDowall, W. (2018) Disruptive innovation and energy transitions: is Christensen's theory helpful? Energy Research & Social Sciences, 37, 243-246

Mitchell, C. (2016) 'Momentum is increasing towards a flexible electricity system based on renewables'. Nature Energy 1, Article no. 15030, Published online 1 February 2016, http://www.nature.com/articles/nenergy201530?WT.mc_id=TWT_NEnergy

Smith, A., Stirling, A., Berkhout, F. (2005) The governance of sustainable socio-technical transitions. Research Policy, 34, 1491-1510

Unruh,G. (2000) Understanding carbon lock in. Energy Policy, 28, 12, 817–830

Unruh,G. (2002) Escaping carbon lock in. Energy Policy, 30, 317–325

Watson, J. et al. (2019) Disrupting the UK energy system: causes, impacts and policy implications. London: UK Energy Research Centre.

Wilson, C. (2018) Disruptive low-carbon innovations. Energy Research & Social Sciences, 37, 216-223

Winskel, M. (2018) Beyond the disruption narrative: varieties and ambiguities of energy system change. Energy Research & Social Science, 37, 232-237