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# The Flexibility Fix: Low-Carbon Energy Transition in the United Kingdom and the Spatiotemporality of Capital

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The ongoing transition from fossil to renewable energy is said by many within the energy industry to require a more “flexible” electricity system. The suggestion is that the variability of renewable energy resources, alongside the increasing load placed on the electricity grid by decentralized renewable generation and the electrification of heat and transport, requires an enhanced capacity to change the spatial and temporal profiles of electricity supply and demand. Drawing on research within the UK electricity sector, this article contends that electricity flexibility schemes might constitute a socioecological fix for capitalism. I discuss Andreas Malm’s claim that the spatiotemporality of renewable energy presents a limit to capital accumulation and suggest that this is a limit that UK flexibility initiatives seek to overcome. The article concludes by suggesting that electricity system flexibility should not be written off as an inherently reactionary sociotechnical project by virtue of its apparent enrollment within the reproduction of exploitative capitalist relations. Rather, I call attention to the political flexibility of electricity system flexibility and, in doing so, further develop ongoing attempts to theorize the socioecological fix in a more politicized manner. *Key Words:* *capitalism, electricity system flexibility, energy, socioecological fix, spatiotemporality.*

In a recent dual-article contribution to the *Annals of the American Association of Geographers*, Ekers and Prudham (2018a, 2018b) set out the most thoroughly developed conceptualization of the socioecological fix to date, describing in detail the ways in which capitalism reworks socioecological relations to avert its crisis tendencies. A rigorous understanding of the socioecological fix, Ekers and Prudham suggested, is a pressing political task, especially given the global transition from fossil to renewable energy currently underway. Indeed, prior to Ekers and Prudham’s papers, McCarthy (2015) argued that renewable energy itself is a socioecological fix for capitalism in the face of the threat posed by climate change to the ecological conditions of accumulation. In this article I build on these associations between low-carbon energy transition and the socioecological fix, focusing on a development that has yet to be addressed within recent attempts by critical scholars (e.g., Labban 2008; Mitchell 2011; Huber 2013; Malm 2016) to understand the changing relationship

between energy and capitalism: electricity system “flexibility.”

Although the global energy system remains dependent on fossil fuels, generation from renewables is increasing. According to the International Renewable Energy Agency (2019a), global renewable energy capacity doubled between 2009 and 2018, with the International Energy Agency (IEA 2019a) estimating that 25 percent of global electricity output and 45 percent of new electricity generating capacity were accounted for by renewables in 2018. In the United Kingdom, where this article is primarily situated, the government estimates that total renewable generating capacity increased by an estimated 11 percent between 2017 and 2018, accounting for one third of the country’s electricity generation at the end of this period (Department for Business and Energy & Industrial Strategy 2019). However, 66 percent of this renewable generation comes from bioenergy, the “renewable” credentials of which can reasonably be called into question

(Behrsin 2019). Although fossil fuels continue to be extracted and combusted at an alarming rate across the planet (IEA 2019a), greenhouse gas emissions continue to rise (Peters et al. 2020), and processes of energy transition remain highly contested and complex (Bridge et al. 2013), bombastic energy industry predictions foresee an irresistible and inevitable socioecological transformation on the horizon.

There seems to be a catch, though. Renewable energy sources are variable in a way that fossil fuels are not, with renewable generation contingent on changes in the weather, seasons, climate, and time of day. In short, the sun does not always shine, the wind does not always blow, and the waves are not always in motion. In *Fossil Capital*, Malm (2016) argued that the variability of renewable energy is difficult to integrate within capitalism, which relies on an abstract spatiotemporality that stands in tension with the place-bound and weather-dependent materialities of renewable energy generation. In the years since *Fossil Capital* was written, however, the energy industry has begun to coalesce around a new solution to this predicament. *Flexibility* has become the buzzword du jour of the energy industry and, I argue in this article, could potentially constitute capitalism's latest socioecological fix—a fix designed, at least in part, to avert the limits to accumulation posed by renewable energy.

Contemporary discourses of flexibility are not exclusive to the energy industry, with the term perhaps more readily associated with the recent emergence of the “gig economy” (Jessop and Sum 2006; Wood 2020). Yet although connections between energy system flexibility and broader economic regimes of flexibility are important (Powells and Fell 2019), this article addresses electricity system flexibility with specificity. In this context, flexibility is about an electricity system's capacity to change the spatial and temporal profiles of supply and demand such that these can be matched. Flexibility is already important within today's predominantly fossil-based electricity system, in which power plants are orchestrated to provide maximum output at the “peak times” when demand is greatest. Yet, for reasons to be explored in detail within the article, the decarbonization of the energy system is said to render flexibility all the more important and, furthermore, to call for myriad new technologies of flexibility such as smart grids, battery storage, and demand-side response initiatives.

The article draws on research conducted within the UK energy industry. Energy industry actors in the United Kingdom are prone to claim that this is a leading context for the development of low-carbon technologies, particularly those associated with flexibility. The article is situated in the United Kingdom not because I take this kind of glowing assessment of the UK energy transition at face value but, rather, out of a desire to subject these hyperbolic claims to some degree of critical interrogation. My interest here is new forms of flexibility within the electricity sector specifically—although, as I go on to explain, heat and transport in the United Kingdom are becoming increasingly electrified, blurring the boundaries between these sectors somewhat. Inspired by Hart's (2018) writings on relational comparison, discussed in further detail soon, I seek to use experiences within the United Kingdom to ground cautious suggestions pertaining to the remaking of energy–capital relations more broadly—abstractions to be treated as tentative working hypotheses in need of further situated empirical enquiry.

The article begins by clarifying theoretical concerns. After then discussing methodological issues, I proceed to develop my core argument around UK flexibility schemes as a potential socioecological fix for the spatiotemporal limits to accumulation posed by renewable energy. The article concludes by calling attention to the political flexibility of electricity system flexibility—an implication that helps inform ongoing debates around the socioecological fix more broadly.

## Renewable Energy and the Socioecological Fix

The concept of the socioecological fix develops Harvey's influential work on the “spatial fix” (Harvey 1973, 1982, 2001). This concept was used to analyze how overaccumulated capital is absorbed through spatial expansion in pursuit of new markets and resources and through remaking existing socio-spatial relations, in particular through investments in fixed capital and the urban environment. By creating new spaces for accumulation, these strategies provide a temporary “fix” for crises of overaccumulation, often “fixing” capital into obdurate physical forms such as urban infrastructure in ways that can only ever be a temporary resolution, akin to the “fix” of the addict in response to their insatiable craving (Harvey 2001).

Ekers and Prudham (2015, 2018a, 2018b) followed Smith in understanding space as a form of produced nature. By extension, Ekers and Prudham (2018a, 2018b) argued, fixed capital and all other sociospatial technologies deployed by capitalism to avoid crisis are necessarily particular forms of produced natures—a premise also emphasized by urban political ecologists (Swyngedouw 2004; Heynen, Kaika, and Swyngedouw 2006; Loftus 2012). As such, Ekers and Prudham (2018a, 2018b) contended that all spatial fixes are socioecological fixes.

Multiple processes are theorized as socioecological fixes within the literature, including biomass wood pellets (Palmer 2021), 1930s Canadian state forestry programs (Ekers 2015), “green” infrastructure investment in Ontario (Nugent 2015), the human body itself (Guthman 2015), and, for McCarthy (2015), renewable energy. Climate change, McCarthy argued, poses a grave threat to the ecological conditions of accumulation. As such, McCarthy contended that climate change is an example of what O’Connor (1991) called the second contradiction of capitalism and, therefore, a rapid and large-scale transition from fossil fuels to renewable energy could potentially constitute a socioecological fix for this imminent crisis.

Underpinning McCarthy’s argument is the premise that it is entirely possible for capitalist social relations to be maintained should a global transition from fossil to renewable energy take place. Yet Malm (2016) called this kind of claim into question. Renewable energy, Malm argued, poses a threat to the spatiotemporal dynamics integral to capitalism. Capitalism has its own specific spatiotemporality, which is, in the terms of Castree (2009), “part of capitalism’s DNA or, if you prefer, it’s operating hardware” (29). Geographers from Harvey (1982) to Massey (2005) have shown that space and time are two aspects of a singular complex and dynamic process—a process that is actively produced through historically and geographically specific socioecological relations. Capitalism, then, produces spatiotemporality in ways adjusted toward the realization of surplus value. The result has been theorized as a spatiotemporality distinguished by its markedly abstract form (Castree 2009).

Marx (1976) described the dual character of labor, distinguishing the “concrete” labor of transforming nature for human use from “abstract” labor, an independent yardstick through which differentiated

concrete labors are made commensurate. As with labor, space and time under capitalism have both concrete and abstract dimensions, with the concrete aspects largely subsumed (although not wholly eliminated) by their abstract aspects (Castree 2009). Precapitalist production was bound to concrete places, for example, by requiring close vicinity to rivers and oceans to facilitate power generation and trade. Similarly, precapitalist production was subject to concrete times, being dependent on environmental changes such as day and night, the passing of the seasons, and the weather. Capitalists, however, have sought to escape the constraints of concrete spaces and times, pursuing boundless mobility and constant circulation. Concrete places and times persist, of course, yet are in large part subsumed by processes of abstraction whereby space and time are actively produced in capital’s own image (Castree 2009). As with labor, the relationship is dialectical, with the abstract and the concrete coexisting as different aspects of the same process (Elson 1976; Ekers and Loftus 2020).

Malm (2016), in his revisionist history of the rise of steam power, argued that coal-based steam was attractive to Britain’s early industrial capitalists because coal can be transported relatively freely, rendering production mobile in a way that was not possible with water-based power. Malm contended that fossil fuels are integral to capitalism because of the ways in which their mobile materialities have helped capitalists to shift production to areas where nature and labor can be more easily disciplined and cheaply procured—thus emerging China as what Malm termed the “chimney of the world.” In this sense, fossil fuels have helped capitalism to produce abstract space, rendering capital’s geographies as less shackled by the biophysical particularities of concrete places and helping capitalists to reshape spatial relations according to the imperatives of accumulation.

Malm, drawing on Castree (2009) alongside Thompson (1967) and Postone (1993), also showed how fossil fuels have enabled capitalism’s production of abstract time. With labor movement victories securing restrictions on the working day, organizing production around the concrete temporalities of rivers—whose flow cannot be aligned with “work hours”—became difficult to maintain. Inert and static coal provided capitalists with a solution to this temporal dilemma, granting capitalists a freedom from water’s “uncooperative” flow (Bakker 2004;

Bakker and Bridge 2006) and powering engines that render capitalists as less subject to the unruly temporalities of nature and labor. Of course, the temporal rhythms of fossil fuel extraction, transportation, and combustion cannot be divorced from the concrete materialities of coal, oil, and gas, as multiple important accounts within energy and resource geography illustrate (Labban 2008; Bridge 2009, 2011; Calvert 2015; Huber 2015). Malm's point, though, is that these fuels render the circulation of capital as less bound to the concrete times of environmental change, enhancing the flexibility of production's temporal rhythms in ways that subsume concrete time to processes of abstraction.

The abstract spatiotemporality dominant within capitalism, Malm suggested, is severely threatened by the prospect of a transition from fossil to renewable energy. Unlike fossil fuels, renewable energy sources cannot be transported around the world: Energy can only be generated in the concrete spaces where sun, wind, or waves are plentiful, undermining the production of abstract space. Moreover, renewable energy has a concrete temporality, given the fluctuating rhythms of the weather, seasons, climate, day, and night. The materialities of renewable energies, therefore, are positioned by Malm as a spatiotemporal limit to capital accumulation. Capitalists' strategy, Malm argued, must then be either to undermine transitions to renewables or else attempt to engineer a more abstract spatiotemporal profile from the concrete materialities of renewables.

Regarding the latter trajectory, Malm considered possibilities for large-scale centralized renewable power plants in places where renewable resources are abundant (e.g., Morocco's failed Desertec project; see Schmitt 2018) alongside interconnected supergrids, battery storage, and demand regulation. His contention, however, was that these potential solutions require forms of collective planning and coordination that capitalists have historically proved extremely resistant toward and that therefore are unlikely to materialize within capitalist social relations. It should be noted that, on this last point, Malm entered complex theoretical territory: Various accounts within regulation theory and Marxian state theory (e.g., Jessop 1982; Jessop and Sum 2006) have argued that capital accumulation is often sustained through state planning and coordination, an argument made with regard to the energy sector by Hirsh (1999). Malm's argument draws on the resistance to cooperation and planning from

Britain's early industrial capitalists in their decision to pursue coal over water-based power. I return later to the pertinence of this argument with regard to the focus of this article on flexibility.

Returning to Malm for now, the implication of his argument is that although some factions of capital might well be pursuing renewable energy as a socioecological fix as McCarthy (2015) suggested, this is no real fix at all for capitalism as a whole. What I want to consider in this article is the prospect of a further socioecological fix for capitalism in the face of the spatiotemporal limits presented by renewable energy: A new fix for an old fix, perhaps? This new socioecological fix in fact coalesces some of the potential routes toward more abstract renewable spatiotemporalities alluded to by Malm under the umbrella concept of electricity system flexibility. *Fossil Capital*, after all, was published five years ago, in which time much has changed in terms of the policy and technological landscape within the energy sector. Indeed, although developments such as battery storage and demand regulation are mentioned only in passing in Malm's text, it is technologies like these that many within the energy industry are now pinning their hopes on in terms of the viability of low-carbon transition. Thus, I turn to the detail of the "flexibility fix" shortly, after a note on methodological issues.

## Methodology

The article seeks to draw conclusions specific to the UK context. That said, drawing on Hart's (2018) work on relational comparison, I am interested in thinking through forms of connection and disconnection between the United Kingdom and experiences elsewhere. The UK electricity system has been shaped by European Union (EU) market liberalization directives, which bring processes of energy transition in the United Kingdom into relation with those underway in multiple other European contexts (Pearson and Watson 2011)—relations reconfigured by the United Kingdom's recent departure from the EU. Many of the utility firms currently playing a leading role in UK flexibility initiatives—for instance, Centrica, EDF, and Iberdrola—are transnational companies operating across multiple contexts globally. UK electricity infrastructures are increasingly enmeshed within global flows of finance capital (Knuth 2018; Hall et al. 2019). The United Kingdom both imports and

exports energy resources across borders. As such, experiences in the United Kingdom cannot be understood as separate from experiences elsewhere and can offer a vantage point through which the coevolution of spatially and temporally extended processes of low-carbon transition and capitalist accumulation can be understood.

Hart's (2018) point, though, is that broader processes are both constitutive of and constituted by contingent situated practices. The capitalist accumulation process, then, does not "touch down" from above in specific historical geographies but rather is the product of the indeterminate mediations of localized agency. Therefore, any attempts to generalize from the UK context to elsewhere must be read as provisional and revisable working hypotheses, in need of further situated research.

The research I draw on within this article consisted primarily of an analysis of key documents produced by a range of UK energy system actors. This included reports and Web pages from multiple sources, documented in Table 1. Document sampling was guided by the goal of incorporating materials from as broad a cross section of UK actors working on flexibility as possible, across public, private, and charitable sectors. Documents were analyzed and coded manually, drawing out underlying themes that structure the argument that follows.

Document analysis was informed and supplemented by six semistructured interviews with anonymous informants working within UK flexibility initiatives, conducted between January and March 2020.<sup>1</sup> Interviews were used to inform my document analysis sampling, to develop my own technical understanding of flexibility issues, and to further understand the rationalities and imperatives underpinning UK flexibility schemes. Informants included representatives of a large energy utility firm, a new energy startup, a distribution network operation firm, a prominent industry consultancy, and a government-backed smart energy communications body.

With methodological issues now clarified, I proceed to develop my argument around the flexibility fix, beginning by contextualizing the UK electricity sector and its nascent flexibility initiatives.

## Contextualizing Flexibility in the United Kingdom

The UK electricity sector was nationalized shortly after World War II, consolidating the establishment

of a centralized electricity grid extending across the country (Cochrane 1985). Processes of privatization and liberalization within the electricity sector began in 1989 under the Conservative Thatcher government, with electricity infrastructure sold off to private firms and new markets in electricity generation and supply created (Pearson and Watson 2011). The emerging model—the so-called British model of liberalization—has now become the default model for the European electricity market, enforced by a series of EU liberalization directives. This is premised on the unbundling of the sector into legally distinct fields of transmission, distribution, generation, and supply (Pearson and Watson 2011).

The UK transmission network is owned and managed by a private firm called National Grid. The transmission network connects to a series of regional distribution networks, operated as regional monopolies under the ownership and management of a number of different private firms. There is then a competitive market in electricity generation known as the wholesale market, within which firms compete to sell electricity to supply companies. Energy supply operates in separation from the material infrastructure of the energy system through a further competitive market, in which firms compete to sell electricity to users. Finally, the electricity sector—alongside the rest of the energy system—is regulated by a body independent of government named Ofgem.

As mentioned in the introduction, the UK energy system is currently in the midst of a period of transition, largely in response to the imperative of decarbonization. As alluded to previously, UK energy industry actors argue that decarbonizing the energy sector underpins the importance of energy system flexibility while requiring new forms of electricity sector flexibility specifically to be developed. I observed two core rationales for this within my research: the need to avoid overloading the electricity grid on the one hand, coupled with the variability of renewable energy on the other. I explain these issues in turn next, with the material set out condensing themes picked up across my document analysis and interviews.

On the first question of the grid, it is generally accepted within the UK energy industry that decarbonizing the energy system would, without mitigating action, place an unmanageable strain on electricity grid infrastructure. The "modern"

Table 1. Documents analyzed

Author(s)	Document title	Year	Document type
Association for Decentralised Energy	Let's Talk about Flex: Unlocking Domestic Energy Flexibility	2020	Report
Bloomberg New Energy Finance, Eaton, Statkraft	Flexibility Solutions for High-Renewable Energy Systems	2018	Report
Carbon Co-op	An Energy System Vision for a Community Energy-Led Future?	2018	Blog
Carbon Co-op, Regen	Local Flexibility Markets: What Are They and How Can Community Energy Organisations Get Involved?	2020	Report
Centre for Sustainable Energy	Smart and Fair? Exploring Social Justice in the Future Energy System	2020	Report
Centrica	Cornwall Local Energy Market	2019	Web page
Delta EE	Smart Meter Benefits: Cost Savings Households Could Make within a Smart Energy Future	2019	Report
EDF	Powering Flexibility	2021b	Report
Electricity North West	Powering the North West's Future Transitioning to a Distribution System Operator—A Collaborative Approach	2018	Report
Energy Networks Association	Open Networks Project: 2019 in Review	2019	Report
Energy Systems Catapult	Towards a Smarter and More Flexible European Energy System	2020	Report
Energy UK, Association for Decentralised Energy, BEAMA	Delivering on the Potential of Flexibility	2020	Report
E.ON	What If You Could Sell the Energy You Don't Use?	2021	Web page
Everoze	Pro Low Carbon: Carbon Impact of DSO Flexibility Services	2020	Report
Flexible Power	Press Release: UK DNOs Collaborate to Deliver Flexible Power	2020	Blog
HM Government	Government Takes Historic Step towards Net-Zero with End of Sale of New Petrol and Diesel Cars by 2030	2020	Blog
HM Government	PM Outlines His Ten Point Plan for a Green Industrial Revolution for 250,000 Jobs	2021	Blog
International Energy Agency	Status of Power System Transformation 2019: Power System Flexibility	2019	Report
International Renewable Energy Agency	Utility-Scale Batteries: Innovation Landscape Brief	2019	Report
Kaluza	Home	2021	Web page
National Grid ESO	Future of Balancing Services	2021	Report
Northern Powergrid	DSO v1.1: Distribution System Operator Development Plan	2019	Report
Octopus Energy	Introducing Agile Octopus	2021	Web page
Ofgem	Future Insights Series: Flexibility Platforms in Electricity Markets	2019	Report
Ofgem	Position Paper on Distribution System Operation: Our Approach and Regulatory Priorities	2019	Report
Ofgem, HM Government	Upgrading Our Energy System: Smart Systems and Flexibility Plan	2017	Report
Ofgem, HM Government	Upgrading Our Energy System: Smart Systems and Flexibility Plan: Progress Update	2018	Report
OVO Energy	Flexibility First: How the UK's Network Companies Can Facilitate Clean, Affordable Energy for All	2018	Report
Piclo	Home	2021	Web page
Power Responsive, National Grid ESO	Demand Side Flexibility Annual Report 2019	2021	Report
Scottish and Southern Electricity Networks	Proactive Flexibility Delivering Smarter Electricity	2021	Web page
Smart Energy GB	Home	2021	Web page
SP Energy Networks	Flexibility	2021	Web page
UK Power Networks	Flexibility Roadmap	2018	Report
Upside	Home	2021	Web page
Western Power Distribution	Flexibility & Flexible Power	2021	Web page

electricity grid was designed around 100 years ago on the assumption that electricity generated in large fossil fuel power plants would flow downward, in one direction, passing through the transmission and then the distribution network before reaching electricity users. Because renewable energy can be generated in more spatially distributed fashions through, for instance, rooftop solar panels, a low-carbon electricity system likely sees sources of generation coming on-stream within the distribution network. With households and businesses becoming electricity producers as well as consumers (or, to use the industry lexicon, “prosumers”), electricity grids now have to cope with the two-way flow of electricity, placing a load on the grid that was not previously anticipated (Powells et al. 2014). This challenge around the capacity of the electricity grid is compounded by the assumption that the decarbonization of heat and transport will largely take place through their electrification, meaning an additional strain on this already overloaded infrastructure. Flexibility pertaining to electricity demand is heralded as the solution to this problem, because if demand was spread more evenly across the day instead of peaking at particular times, the load placed on the grid at any one time would become more manageable.

The second factor underpinning the UK energy industry case for flexibility in a low-carbon energy system is, as alluded to previously, the variability of renewable energy sources. Given that generation from renewable energy sources will peak in particularly sunny or windy periods, matching supply and demand will be far more straightforward if demand can be arranged to coincide with fluctuations in the weather, climate, and time of day—if, for instance, demand could peak at noon when the sun is strongest, rather than in the evening when people return home from work.

A number of new technologies are positioned by the UK energy industry as integral in the move to a more flexible electricity system, coalescing around the concept of the *smart grid*. Smart electricity grids deploy information and communications technologies such as smart meters and smart appliances to facilitate the real-time flow of electricity use data between users and utility companies. In addition to allowing for increasing accuracy in the measurement of electricity consumption, smart energy technologies provide the infrastructural basis for what has become known as *demand-side response* (DSR). DSR

initiatives offer financial incentives to electricity users for shifting their demand to off-peak periods or toward periods coinciding with surges in renewable generating capacity.

Battery storage, meanwhile, provides an opportunity to make both supply and demand more flexible (although not without worrying political and ecological consequences, owing to the dispossession and ecological degradation bound up with lithium mining projects; Anlauf 2016). Batteries allow electricity generated at particularly sunny or windy periods to be conserved and then discharged later, when renewable generating conditions are less amenable. Moreover, batteries can help reduce the load placed on electricity infrastructure by charging at off-peak times and then discharging when needed. Indeed, although electric vehicles are on the one hand a source of additional strain on the electricity grid given the demand they create, industry actors argue that they can simultaneously function as mobile batteries, charging at off-peak times (e.g., at night) and feeding back into the grid at peak times, thereby reducing the strain they create. Meanwhile, industry actors suggest that electric heat pumps can be made smart so that, similarly, they use electricity at off-peak times. Alongside “behind the meter” storage systems operated by domestic and commercial energy consumers, much larger utility-scale storage schemes are also imagined as crucial within the decarbonization of the sector (International Renewable Energy Agency 2019b). These include, for example, large-scale battery units, pumped-storage hydroelectricity, and wind turbines with compressed air storage, alongside multiple other technologies.

Despite widespread acknowledgment of the importance of low-carbon flexibility technologies from across the UK energy industry, smart grid and DSR schemes are still in their infancy. A number of industry trials and pilot projects are currently underway to test and develop these technologies, usually led by large incumbent utility firms working in collaboration with universities, often with government funding (see, e.g., Centrica 2019; EDF 2021a; Project LEO 2021). Alongside incumbent actors, myriad smaller firms and startup enterprises have emerged within the nascent UK flexibility sector. These new players are taking on a range of roles, including developing and trialing new technologies (e.g., Octopus Energy 2021a), creating new market platforms through which flexibility can be procured



(e.g., Piclo 2021), and acting as aggregators that coordinate DSR from individual electricity users to meet grid operator requirements (e.g., Social Energy 2021). Aggregators, alongside large-scale electricity users capable of providing a significant amount of load, participate in competitive market platforms within which flexibility is bought and sold as a commodity. Currently, the UK transmission network operator National Grid, alongside many of the multiple distribution network operators and a number of third-party private firms, run their own flexibility platforms. As such, there is no single platform for the provision of flexibility in the United Kingdom but, rather, several competing markets, which is a cause for concern according to market regulator Ofgem (2019a), as discussed later.

With the context of electricity system flexibility in the United Kingdom now explained, the next section proceeds to develop my argument around flexibility as a socioecological fix.

## The Flexibility Fix

Although recent developments around electricity system flexibility and low-carbon transition have yet to become a core concern for energy geographers, there are some notable exceptions. Powells et al. (2014) emphasized the need to center the specific social practices enrolled in flexibility initiatives in future policy and research, and Powells and Fell (2019) examined questions of distributional justice through a Bourdieusian analysis of flexibility as a form of capital (Bourdieu 1986). Bulkeley, Powells, and Bell (2016) understood the smart grid in Foucauldian terms, as entailing novel notions of good energy conduct that dovetail with the rationale of demand-side response. Levenda and his collaborators, meanwhile, understood the smart grid as a disciplining force in the creation of neoliberal subjectivities and ideologies of entrepreneurial urbanism (Levenda, Mahmoudi, and Sussman 2015; Levenda 2018, 2019).

In what follows, I draw on these contributions to help cast flexibility in a new light, namely, as a potential socioecological fix for capitalism. Electricity system flexibility initiatives in the United Kingdom, I contend in this section, constitute an attempt to render renewable energy's spatiotemporal-ity more abstract and, in turn, to avoid associated limits to accumulation. To make this argument, I

begin by addressing questions of spatiality, before moving on to address the temporal dimension of the flexibility fix. In a final subsection, I address the ways in which failures of coordination might hold back flexibility's potential as a socioecological fix.

## Spatial Limits

Addressing the question of spatiality first, the electricity grid has historically been a technology through which abstract space has been produced. Prior to the advent of the electricity grid, electricity consumption was tied to the concrete places in which electricity was generated. The grid facilitates the flow of electricity across space, allowing free mobility for capital across the landscape within which the grid extends. Although Malm (2016) documented how many of the early advocates of renewable energy imagined that global production could be reorganized around the concrete places in which renewable electricity can be generated, he noted that this vision is entirely incompatible with capitalism's production of abstract space. If the dominance of abstract space is to be maintained, a means of integrating renewable generation into the spatially extended grid must be found. Given that, as explained in the previous section, flexibility is the UK energy industry's solution for integrating renewables into the grid in a way that avoids overloading it, flexibility in turn becomes a tool for facilitating capitalism's production of abstract space.

What's more, it is worth noting the particular importance of the automobile in capitalism's socio-spatial dynamics—and the role of electricity system flexibility in enabling dominant cultures of automobility to be sustained. Huber (2013) documented how the privatized mobility of the car has become integral to a neoliberal regime of atomized social reproduction. The automobile and, in turn, oil have become integral to capitalism's subsumption of concrete space to abstract space, rendering landscapes as more easily traversable. It should be no surprise, then, that the reproduction of private automobility is usually treated as a nonnegotiable necessity of low-carbon transition within the UK energy industry. As such, the electric vehicle (EV) takes center stage. This was recently seen, for instance, in the United Kingdom with the government's prioritization of EVs within its ten-point Green Industrial Revolution plan (HM Government 2021) and its

announcement of a £1.8 billion investment in EV infrastructure (HM Government 2020).

The importance of EVs within the UK energy industry's development was emphasized at a number of points in my interviews with Alex, a member of an Innovation team from one of the United Kingdom's so-called big six utility firms,<sup>2</sup> as well as Reese, the head of a UK distribution network operator's Smart Grids team. Their comments simultaneously speak to the rapid growth of the sector alongside industry actors' unmitigated enthusiasm around this:

Now the question about EVs is not if, it's when. (Reese)

Obviously EVs is a huge area. And will get much, much bigger. ... Like, everyone loves Tesla, I like Tesla, I wish I could afford one! Umm, but you are seeing not only, like, some of the early movers to market. ... You're seeing Ford really pushing, you're seeing Peugeot really pushing, Fiat Group, Chrysler Group, come to market with big offerings in a big, big way this year and next year. And so that's huge. (Alex)

UK industry actors (see, e.g., Ofgem and HM Government 2017; Northern Powergrid 2019; Energy UK, ADE, and BEAMA 2020) are agreed that the mass adoption of electric vehicles is contingent on the effective realization of new electricity system flexibility measures—otherwise, as has already been explained, the load on the electricity grid would be too great.

To summarize the point around EVs, because the command over space produced via privatized automobility has become an unquestioned commonsense necessity within neoliberal capitalism, EVs are imagined as essential in the low-carbon transition. Yet because of the additional strain this places on the electricity grid, flexibility is seen as essential for its achievement within the UK context. Again, capitalism's production of abstract space becomes contingent on flexibility.

As might be expected given the partial and incomplete character of the socioecological fix, however, it appears doubtful that flexibility can fully enable the abstract spatiality of fossil capital. Malm showed how the mobility of fossil fuels enabled the globalization of capital accumulation. Coal, oil, and gas can be transported to be combusted in places far away from the initial concrete places of their

extraction—allowing capitalists to circumvent high labor costs and unruly natures. This, plainly, is not possible with the sun, wind, or waves. Electricity generated by a particular wind farm, for instance, can be transported across space to anywhere connected to the grid within which this wind farm is integrated. Yet, at present, although electricity grids do transcend national borders, the current mechanisms for transporting fossil fuels across the globe (via trains, trucks, shipping, pipelines, etc.) allow for a far greater degree of global interconnection than existing cross-border electricity grid connections can facilitate. Put differently, although China, for example, has become what Malm termed “the chimney of the world” through coal and oil imports from multiple countries across the world including Australia, Indonesia, Russia, Iran, Saudi Arabia, and many more (Energy Information Administration 2020), there currently exists nothing close to an international supergrid that might allow for anything like a comparable flow of electricity across space.

Should capitalists be disarmed of this kind of global mobility, this would surely be a spatial limit sufficient to threaten severe crisis. Averting this crisis perhaps calls for the kind of global systems of flexibility enabled by nothing short of an international supergrid—it will be interesting to see whether the energy industry takes steps in this direction over coming years. The IEA certainly seemed to acknowledge the need for greater international collaboration around flexibility, writing in a recent policy paper:

Greater inter-regional and international co-ordination can unlock flexibility and yield significant economic benefits. Transmission interconnectors can enable the sharing of flexibility resources across diverse geographies and jurisdictions, including those with distinct market rules and governance structures. (IEA 2019b, 15)

### Temporal Limits

Flexibility, then, can serve as a socioecological fix for the spatial limits to accumulation associated with decarbonization—albeit a fix that looks, at least at present, incapable of achieving the global command of space that capitalism has become reliant on. What, then, of the question of temporality? My suggestion is that UK flexibility initiatives are being imagined and developed as inhibitive of the dominance of abstract time, yet in ways that seek to

render this as nondisruptive as possible for capital accumulation.

As established previously, the variability of renewable energy implies a concrete temporality difficult to integrate within capitalism's production of abstract time. It remains possible that electricity storage technologies could allow for a more abstract temporality to be produced from renewable sources. Should these technologies become developed sufficiently and their economics stack up, storage would potentially provide a way around the concrete weather-dependent times of renewables. At present, though, there does seem to be broad agreement among UK industry actors that DSR will be necessary alongside storage (see, e.g., UK Power Networks 2018; Ofgem 2019b; Power Responsive, and National Grid ESO 2021). DSR initiatives use financial incentives to encourage electricity users to organize their electricity consumption around the concrete times of renewable generating surges, in turn rendering the temporalities of production and reproduction as subject to more concrete temporalities. There are interesting questions, however, around the extent to which concrete temporalities are imposed, the ways in which this happens, and whose temporal rhythms become more concrete and whose are less so.

For one thing, many within the UK energy industry imagine that domestic flexibility is likely to be enacted through automated technologies (see, e.g., Ofgem and HM Government 2017; Electricity North West 2018; Energy UK, ADE, and BEAMA 2020). The idea here is that smart home devices (e.g., Amazon's Alexa) would monitor electricity price fluctuations and turn appliances on and off according to preprogrammed algorithms. If automated in this way, domestic flexibility would introduce forms of concrete temporality in ways that minimize noticeable changes to daily reproductive practices. Ian, an employee of a government-backed communications body promoting the smart meter rollout, made it clear that, for him, automated flexibility was necessary to avoid more fundamental social change:

We're going to have to do most of the heavy lifting, I suspect, through systemic changes and automated changes so that people don't have to make the change. ... The point at which I have to choose to turn on my washing machine at night is the point at which most of us aren't going to. So it will fail. The point at

which it's automated for us is the point that most of us won't override that so it could succeed.

Ian acknowledged, however, that a challenge in this regard is ensuring that this automated technology is accessible to all, irrespective of financial means. In the terms of Powells and Fell (2019), flexibility is a form of capital (akin to Bourdieu's [1986] concept of social capital) that is distributed unevenly, with one's ability to benefit from flexibility technologies contingent on vectors of difference such as class, gender, and age.

In particular, energy anthropologist Charlotte Johnson (2020) showed how capitalist class and gender dynamics might see many lose out on the benefits of automated flexibility. If working-class households were financially excluded from automating DSR, the gendered division of labor integral to capitalism would likely see working-class women burdened with the additional labor of manually orchestrating DSR, for instance, by carefully planning washing and cooking practices around fluctuating price signals. Indeed, this was what Johnson observed happening in her research on a DSR trial in the East London borough of Tower Hamlets. It seems likely, then, that although the widespread promotion of demand-side response would render social reproduction as more grounded in concrete time for all, the ways in which this translates as fundamental changes within everyday life will be contingent on power-laden vectors of difference.

Indeed, moving from domestic to commercial and industrial consumers, the extent to which the latter will integrate the concrete temporalities of demand-flexibility remains unclear. A number of industry flexibility trials in the United Kingdom have struggled to substantively engage commercial and industrial users in providing demand flexibility. For instance, Oliver, a business analyst from a large utility firm, discussed the limited participation of commercial and industrial actors within a local flexibility market trial he is working on.<sup>3</sup> Commenting on this, he said:

It was actually very difficult to get people [commercial and industrial energy users] to sign up here because of the way the trials were and the fact that the DNO [distribution network operator] markets are very nascent, there's not actually that much revenue available. ... And ultimately, the business needs to make money in order to invest. ... Anybody whose main aim was to make money and all about the financial were ultimately put off from participating.

I also discussed the question of industrial and commercial uptake of flexibility with Emma, an energy industry consultant specializing in flexibility. Speaking about this, Emma commented:

So we see people like big tech giants like Apple and Amazon and Microsoft, going out and procuring renewable energy directly through power purchase agreements, PPAs. There is a question to what extent they go the next step and then also think about flexibility. Because it's one thing to buy a certain number of kilowatt-hours from renewables. But are they generating when you'd be consuming the energy? Answer is not ... you know, there's not a direct match there.

Emma stressed her optimism that this situation could change. Yet, at present, it remains to be seen whether commercial and industrial users will buy in to demand flexibility in any meaningful way. What does seem clear, as we might predict, is that the key factor in determining this will be whether the financial incentives of engaging flexibility outweigh the limits to accumulation posed by more concrete temporalities of production. As such, a scenario in which industrial and commercial users become more electricity-flexible is one in which, as per my broader argument, more concrete temporalities are introduced in ways that are as minimally disruptive to accumulation as possible. Should, on the other hand, industrial and commercial users fail to become more flexible in their electricity usage in any significant way, we might see a scenario in which social reproduction becomes reoriented around the more concrete times of renewable generation to provide the flexibility for capitalists to maintain a more abstract temporal profile in their value-extracting endeavors. It is worth noting that there is already a precedent of social reproduction being reworked as a socioecological fix for capitalist crisis, as established by Guthman (2015).

To summarize the argument made around flexibility and temporality, then, although the UK industry consensus around the need for DSR is in some ways an acknowledgment that the temporality of capitalism must become more concrete, there are nascent signs that UK flexibility schemes might render a more concrete temporal profile as amenable to accumulation as possible. We might, then, still speak of flexibility as a partial socioecological fix to the temporal limits to accumulation presented by renewable energy—as well as a partial socioecological fix to the spatial limits to accumulation, as established previously.

An alternative scenario not considered here is that the state enforces more concrete temporalities on capital via direct regulation necessitating demand flexibility for commercial and industrial users. Yet there are, thus far, no signs that this kind of collective planning and coordination are emerging—an observation that I explore in some more detail now.

### Capitalism versus Coordination

Malm's original contention was not that establishing a more abstract spatiotemporality from renewables is impossible. Rather, Malm's point was that doing so would require forms of collectivity and coordination that capitalists have at times resisted and that therefore are unlikely to emerge within capitalist social relations.

Many energy industry actors currently argue that the development of flexibility in the United Kingdom is being held back by a fragmented approach, lacking in coordination. A recent policy report by UK energy market regulator Ofgem (2019a) is illuminating in this regard. A central conclusion of this report is that:

... the current environment is one where different proprietary technologies are being simultaneously developed. There is duplication in activity and a risk of locking in a future world which doesn't achieve some of the key benefits that flexibility and a mature Flexibility Platform sector could deliver. ... In this quickly developing area, there could be significant benefits from a coordinated approach, focused on the beneficial outcomes to consumers, the grid and the companies who operate in this space. (3)

As noted previously, there are currently multiple different competing platforms allowing for flexibility to be procured and traded in the United Kingdom. Firms running the country's distribution and transmission networks therefore attempt to balance the grid through operating across several distinct flexibility markets. Ofgem's (2019a) report outlines a spectrum of options for organizing flexibility, ranging from the current uncoordinated multiplatform competition through to one single coordinated system. Ofgem noted that the present arrangement risks higher costs and a failure to realize the full benefits of flexibility due to a lack of coordination—as per the preceding quote. Yet the criteria used in the article to evaluate differing flexibility arrangements are highly telling. More coordinated approaches are

assumed to limit innovation within the article—yet no evidence is given to substantiate this assumption. Meanwhile, the need to directly regulate a platform is seen as a disadvantage in and of itself, with no explanation. Similarly, that “market forces” are allowed to shape a platform is seen as an inherent advantage, again without justification. The report, then, explicitly makes the case for more coordination, yet simultaneously presents a number of factors to be cautious about doing so, which seem very clearly to be rooted in the commonsense presumptions of neoliberal capitalism. The point was concisely summarized in my interview with flexibility consultant Emma. When I asked Emma whether a lack of coordination was a barrier to the development of flexibility schemes, she replied, “Yeah, absolutely. ... That’s the result of our liberal market structure. That’s directly linked.”

This ideological imperative and its shortcomings were extremely clear in the government’s attempt to rollout smart meters—a core infrastructural component of low-carbon flexibility. The United Kingdom’s smart meter rollout has been besieged by difficulties: The initial government target, set in 2013, was that all households would have a smart meter by 2020, yet at the time of writing uptake is at only 40 percent, with the deadline now moved back to 2024 (BBC News 2019). I discussed the challenges of the rollout with smart meter communications body employee Ian. In his words:

I think there are questions around the delivery body for doing this. So, it is normal when you do national infrastructure that you have a single delivery body. If you look at Digital UK for digital or even Locog for the Olympics. For this [the smart meter rollout] being put in the hands of energy suppliers does create a different dynamic.

In several other European countries, smart meter rollouts have been overseen by distribution network operators, allowing one body to oversee and coordinate the program (Zhou and Brown 2017). In the United Kingdom, the rollout has been led by supply companies—the multiple competing firms responsible for contracting electricity to users. This was a decision taken for the ideological reasons alluded to in the 2019 Ofgem report. Ian told me:

There was a case at least that you do a supplier-led rollout. And use the power of the market to deliver services and reduce prices. That’s the kind of, you

know, the kind of liberal economics argument for why you would do it that way.

The issue with this logic, Ian concludes, is as follows:

So, one of the conditions for a successful infrastructure upgrade is kind of single-minded good quality governance. We’ve got sixty suppliers doing their own thing, so that is inherently more difficult to be successful in it.

Pulling together the Ofgem report and the challenges of the UK smart meter rollout, it seems that Malm’s prediction rings true with regard to the development of electricity system flexibility in the United Kingdom, the potential of which is being inhibited by the preference for competition over coordination that often characterizes sociotechnical governance within capitalism. Whereas, as mentioned previously, arguments from regulation theorists and others give grounds for caution around Malm’s conceptualization of capitalism as antithetical to collaboration, it seems as though the dynamic he pinpointed is indeed playing out within nascent UK flexibility schemes.

Therefore, to summarize the argument of this section, UK electricity system flexibility schemes point toward a potential socioecological fix for capitalism in the face of the concrete spatiotemporalities of renewable energy but seem to be constrained as a fix for this limit on three counts: an inability, thus far, to facilitate the global command of space that capitalism pursues; a failure to avoid at least a partial introduction of more concrete temporalities; and an absence of coordination and collaboration that has detracted from flexibility initiatives’ effectiveness.

## Conclusion

This article has argued that the ways in which flexibility initiatives are being imagined and devised in the United Kingdom implies a possible socioecological fix. Spatially, UK flexibility schemes appear to offer capital mobility across the landscapes through which the grid stretches and help reproduce the command of space achieved by private automobility. Temporally, UK flexibility initiatives enable a move toward more concrete temporalities of production and social reproduction in ways that prove minimally disruptive to accumulation—either by making

the adoption of more concrete temporalities profitable or by shifting the burden of concrete temporalities toward social reproduction. Yet the fix for capitalism provided by UK flexibility measures in both spatial and temporal terms is, I have argued, partial and incomplete. For these schemes, at present, fail to allow for the global command of space currently pursued by capitalists; they fail to preserve the abstract temporal profile capitalists have come to demand; and their effectiveness as a fix seems to be conditional on forms of collective planning and coordination that are currently missing in the United Kingdom.

Hart's (2018) work on relational comparison implies that a more "general" theory of the flexibility fix would require further comparative research into discourses and practices of flexibility across diverse spaces and times. Yet, in Hart's own words:

What are typically seen as bounded "units of analysis" are often more usefully understood as vantage points from which to try to begin to grasp the coming together and interconnections of what (at least initially) appear as key processes. (389)

Thus, we must recognize that UK flexibility schemes are themselves enmeshed within relations stretching way beyond the landscape of the UK energy system. To the extent that flexibility schemes being devised and deployed elsewhere are responding to similar spatiotemporal issues raised by low-carbon transition, it seems reasonable to hypothesize that flexibility could potentially serve as a socioecological fix for capitalism beyond the UK context. Yet nothing more than a tentative suggestion can be made at this point, without further empirical investigation.

Is electricity system flexibility, then, inextricably bound up with the violence and exploitation of capitalism? I think not. That technologies of flexibility are currently enrolled in enabling capitalist accumulation is not in itself a reason to suppose that these technologies could not be repurposed to support alternative socioecological trajectories. For the socio-technical trajectories realized with the aid of a certain technology are shaped through the coevolutionary interplay of the specific spatial-material characteristics of this technology and the socioecological relations within which it is enmeshed (Harvey 2003).

Indeed, although flexibility might constitute a fix for capitalism, its present-day implications cannot be reduced to this alone. For example, a blog post

written by Carbon Co-op (2018)—a Manchester-based cooperative providing energy services, advocacy, and education—illustrates the increasing prevalence of a "Thatcherite" vision of atomized "prosumers" benefiting from technological developments and subsidies to become less dependent on the electricity grid, in turn shifting the costs of maintaining grid infrastructures to lower income households unable to afford this kind of energy autonomy. Echoing an argument made within Graham and Marvin's (2001) *Splintering Urbanism*, Carbon Co-op suggested that avoiding a hyperliberalized and inequitable energy future means recognizing the continued importance of the electricity grid as "an embodiment of a kind of socialism—a pooling of resources for shared needs" (Carbon Co-op 2018) and, in turn, ensuring that renewables can be integrated into the grid. To the extent that electricity system flexibility is necessary for achieving this, it is to my mind commendable in this regard.

Further, although some of the extreme-localist early advocates of renewable energy might have venerated a move toward the concrete places and times of renewable generation, anticapitalists should surely be asking what kind of spatiotemporal horizons are desirable, rather than blindly romanticizing the concrete and objecting to abstract spatiotemporality per se (see Ekers and Loftus [2020] for a critique of the fetishization of the concrete). Technologies of electricity flexibility could conceivably help us to collectively engineer more liberatory spatiotemporal rhythms of socioecological life. Accordingly, it is important that those of us with an interest in building alternative futures understand these technologies and remain open-minded as to their political implications.

As such, my contention is that electricity system flexibility is flexible in its political implications, which depend on the socioecological relations within which technologies of flexibility are situated. The political flexibility of socioecological fixes more broadly has, I believe, been inadequately captured within the literature so far. What has perhaps not been made explicit enough is the need to avoid understanding those socioecological practices and processes identified as helping capitalists to avert crisis as reducible to nothing other than fixes for capitalism. To emphasize that socioecological phenomena enrolled as fixes for capitalism might, via the unpredictable contours of political ecological

struggle, function radically otherwise is, then, to contribute to Ekers and Prudham's project of a more politicized account of the socioecological fix. This, in turn, further exposes "slippages, openings, and contradictions" (Hart 2018, 375) within the accumulation process, prying open further room for divergent socioecological futures.

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## Notes

1. Research participant names are changed within the article to preserve anonymity.
2. The "big six" is the colloquial name given to the six firms that have traditionally dominated the UK energy retail market: British Gas, EDF, E.ON, Npower, Scottish Power, and SSE.
3. The location of this trial is unspecified in the article to preserve my research participant's anonymity.

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