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Conceptualising Flexibility: Challenging Representations of Time and Society in the Energy Sector

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Abstract

There is broad agreement that the need to decarbonise and make better use of renewable and more intermittent sources of power will require increased flexibility in energy systems. However, organisations involved in the energy sector work with very different interpretations of what this might involve. In describing how the notion of flexibility is reified, commodified, and operationalised in sometimes disparate and sometimes connected ways, we show that matters of time and timing are routinely abstracted from the social practices and forms of provision on which the rhythms of supply and demand depend. We argue that these forms of abstraction have the ironic effect of stabilising interpretations of need and demand, and of limiting rather than enabling the emergence of new practices and patterns of demand alongside, and as part of, a radically decarbonised energy system. One way out of this impasse is to conceptualise flexibility as an emergent outcome of the sequencing and synchronisation of social practices. To do so requires a more integrated and historical account of how supply and demand constitute each other and how both are implicated in the temporal organisation of everyday life. It follows that efforts to promote flexibility in the energy sector need to look beyond systems of provision, price, technology, and demand-side management narrowly defined, and instead focus on the social rhythms and the timing of what people do.

“[A]bout 3GW of new flexibility [has been] contracted since 2016...” (BEIS, 2018: 6)

“New sources of flexibility could reduce the cost of the UK energy system by billions of pounds cumulatively by 2030.” (Carbon Trust and Imperial College, 2016: 6)

“By 2030, the UK could benefit from 11GW of additional flexibility, equivalent to 18 per cent of current generating capacity...” (Froggatt and Quiggin, 2018: 344)

Introduction

For those new to the field, the notion of quantifying temporal flexibility in energy consumption or provision and representing it in units of GW or pounds is really very strange. The capacity to be flexible is not usually understood as something that can be bought, sold, and measured in precise units. What is it exactly that is being valued and exchanged in the flexibility market? How is flexibility produced, and by whom? These questions bring us face to face with more fundamental issues about how time and activity are represented, and how such representations matter for the practicalities of infrastructural development and provision.

Each of the statements listed above has one thing in common: all depend on representations of flexibility that are abstracted from the details of how daily life is organised and from any understanding of how demand and supply constitute each other within and over time. As such, all exemplify a tendency that prevails (not only) in the energy sector, to suppose that the timing of demand can be somehow detached from particular moments and uses of energy, and from the rhythms of daily life. In taking stock of the ‘work’ involved in purifying and constructing discourses of flexibility (arguably a precursor for making markets – see, for example, Callon et al., 2007), we take a step back and use this case to revisit assumptions that are made about temporality within the energy sector and to consider their effects.

When it comes to energy and especially to electricity, the significance of timing is not new. From the start, electricity providers have faced challenges in balancing supply and demand, and of doing so in ‘real time’. Since electricity is difficult to store, deliberate efforts have to be made to manage peaks and troughs in demand during the day and also over the year (see, for example, Hughes, 1993). Sometimes these efforts involve switching on additional supply when demand peaks – classically when people return home from work on winter evenings, or when there are major sporting events on television. Other methods include shifting electricity demanding activities to out of peak hours: for instance, incentivising off-peak consumption with time of use tariffs (e.g. Economy 7 and its commercial equivalents) or encouraging people to set the washing machine going when national energy demand is low.

Over the last decade or so, the need to decarbonise electricity supply and make better use of renewable sources of energy (including wind and solar) has increased the significance of when energy demand occurs. In simple terms, renewable energy is not always available at times when the need for it is high: wind is intermittent and unpredictable, and the sun does not shine on dark winter nights. In many countries, plans for decarbonisation include increasing the use of electric vehicles. This is likely to compound the problem if people charge electric vehicles when they get home from work. In thinking about the implications of innovations like these, experts in the field anticipate that systems of provision will become more complicated, and more diversified. Froggatt and Quiggin (2018) expect that there will be more organisations and actors involved, not only providing and consuming electricity, but also actively managing or aggregating demand, shifting load, and delivering ‘non-consumption’ back to the grid for a price, or selling the potential for storage, along with other so-called flexibility products and services. It is in this context that interpretations of

flexibility as the commodified potential to shift the timing of energy-use and energy supply have taken hold.

In the first part of the paper, we review the ways in which flexibility is conceptualised by energy providers, aggregators and merchants, as well as by policy makers and energy researchers. In detail, we distinguish between accounts that treat flexibility (1) as a quality or property of the energy system as a whole; (2) as a commodity that can be bought and sold, and (3) that operationalise it in the form of specific measures, instruments, or techniques such as storage or demand-side management.

This exercise reveals two significant tensions. The first is that although aspects of supply and demand are both present in engineering and economic discussions of flexibility, narratives about increasing flexibility rest on remarkably stable, typically unwavering interpretations of energy demanding practices, and of when these occur. In short, abstracted discourses of flexibility concentrate on how 'needs' can be met but take the needs themselves for granted. The second tension is that since measures and forms of flexibility are real in their effects (they are performative), they have the effect of stabilising (strengthening) rather than 'flexing' (weakening) existing social-temporal rhythms. Our analysis of these two features suggests that the contemporary flexibility industry has the ironic and unintended consequence of reducing the scope for fostering forms of social-temporal organisation that might result in more open and, in our terms, more flexible patterns of demand.

In the second part of the paper, we step away from contemporary representations of flexibility in the energy sector. Starting afresh, we make the case for conceptualising flexibility as an emergent outcome of social practices and their connections, including forms of sequencing and synchronisation. Instead of treating flexibility as a quality of an energy system, or as a feature of specific technologies, consumer groups, or social practices, we define it as the potential for reconfiguring the temporal organisation of social life and the energy demands that follow.

Although it is consistent with much that has been written about time and society, this way of understanding flexibility is fundamentally and ontologically different to the dominant representations that we review. Rather than trying to patch this approach onto existing discourses, we argue that reconceptualising flexibility along the lines we suggest reframes the policy challenges that lie ahead. In the final section, we comment on what policymakers might do to engender temporal patterns that are better matched to renewable energy supply than those with which we are familiar today.

Part 1: Representations of Flexibility in the Energy Sector

In *We Have Never Been Modern* ([1993] 2012), Latour argues that "[t]he connections among beings alone make time."¹ (77) His point is that it is beings and their relationships – networks – that construct what has been considered to be the temporal passing of modernity. In this paper, we are similarly interested in how contemporary representations of flexibility conceptualise and in a sense 'make' time and energy. This is not just an interest in the construction of discourse for its own sake. Ideas about how energy demanding practices and patterns of energy consumption connect have

¹ See discussions of temporal abstraction in Sutherland T. (2013) Clocks, calendars, and temporal abstraction. *Time & Society* 22: 410-414 and his review of Birth K. (2012) *Objects of time: How things shape temporality*: Springer.

effect: mattering directly for how supply and demand are managed and understood, and how issues of timing and flexibility are attended to, problematised, and intervened in.

Having characterised the representations of flexibility implicit in energy-related debates, we change gear, and in part two, return to Latour's injunction. We take on board the suggestion that time is best understood as an outcome of the connections between beings. From this it follows that the spatiotemporal flexibility of everyday life should be understood as an emergent outcome of connections between practices. But this is to run ahead. First, we map out the terms in which flexibility figures in contemporary discussions of energy and energy management.

Reifying flexibility: Flexibility as a quality of whole energy systems

The concept of reification has a history of its own, but here we take the term to mean the transformation of human properties, actions, and relations into the properties, actions, and relations of human-made things, which in turn act back on and govern human activity. In conceptualisations that *reify* flexibility, qualities of human activities involved in the generation and use of energy are taken out of their spatial, temporal, and various other kinds of contexts, treated as a property of the energy system as a whole, and then measured in giga/mega-watts. A 2011 report by the International Energy Agency exemplifies this approach, defining flexibility as:

"... the extent to which a power system can modify electricity production or consumption in response to variability, expected or otherwise. In other words, it expresses the capability of a power system to *maintain reliable supply* in the face of rapid and large imbalances, whatever the cause." (International Energy Agency, 2011: 35 italics added).

Building on this definition, methods have been developed to quantify the amount of flexibility that national power systems 'contain'. Such techniques make it possible to identify countries that are, in these terms, more or less flexible than others. This understanding is consistent with other 'whole system' approaches and with related ideas about balancing and optimisation. Such representations underpin physics and engineering-based narratives of energy systems and economic accounts of flexibilities in energy markets. For those embedded in this paradigm, flexibility at the system-level is expected to become increasingly important. Poncela, Purvins, and Chondrogiannis observe that: "Higher flexibility in the future generation fleet and power demand are likely to play an essential role in *maintaining secure operation of the power system*" (2018: 1 italics added). Its importance is such that some commentators speculate that: "... [whole system] flexibility may at times and in certain places supersede the need for component efficiency, in order to improve overall system efficiency."² (Grunewald et al., 2018: 58)

In talking about flexibility in this way, physicists, engineers, and economists treat it as a quality not of connected human activity, but of energy systems imagined as machines which act and respond to balance demand in the face of external pressures. This idea of equilibrium is rooted in ideas about the importance of maintaining the capacity to *meet* demand at all times and in a commitment to maintaining what is known as the security of supply. Although some sources of whole system flexibility are considered to lie in the hands of consumers, estimates and models emphasise the rates at which providers can modify supply. If demand-side responses and demand reductions are to figure in such equations, they have to be represented and quantified in equivalent terms. As a result,

² For a critique of the idea of energy efficiency see Shove E. (2018) What is wrong with energy efficiency? *Building Research & Information* 46: 779-789.

opportunities for modifying demand are treated, and therefore, identified and acted upon as if they could be turned up and down, just like sources of energy supply.

In seeking to balance input and output and *meet demand* over seconds, minutes, hours, and days, 'whole systems' representations of flexibility construct, respond to, and perpetuate an imagined 'baseline'. This baseline figures as an established *need* for energy which has effect in plans and forms of investment that in turn have effect in constituting demand in the longer term, that is, over decades and centuries. Rather than being part of the story, questions about what it means to 'maintain reliable energy supply' - what is enough supply, how this is defined, and what counts as reliable – are typically taken for granted.

Commodifying flexibility: Flexibility as a resource that can be bought and sold

A second method of representing flexibility is to define it as a resource that can be bought and sold. This approach, closely related to the 'whole systems' interpretations described above, also reifies flexibility and treats it as a property of an energy system, but with an additional emphasis on the costs of balancing input and output in the energy market. To commodify flexibility is to put a price on the potential to shift specific loads and uses of energy from one time and place to another.

Flexibility is not only measured in terms of gigawatts (standard units that can be compared at any time and anywhere across a whole system), it is also given a value that reflects and relates to the timing and location of where energy use is shifted from and to. While dynamic time pricing is not at all new – there are, for instance, off-peak fares and rates for all sorts of services - what is distinctive is the notion of buying and selling the potential to shift the timing of demand. The idea that there is, or that there could or should be a market for flexibility itself, within or linked to the markets through which electricity is bought and sold, has become a central part of the decarbonisation agenda and part of a repertoire of policy instruments designed to increase the share of renewable energy supply.

The commodification of flexibility depends on putting a price on non-consumption (see the concept of 'negumption' in Shove and Chappells, 2001: 55; and also ideas of 'negawatts' in Lovins, 1996, and 'negamiles' and 'negamarkets' in Wieman, 1996), and on valuing different attributes, including the timing of non-consumption and the rate at which it can come 'on stream'. As a report for the Oxford Institute of Energy Studies notes, "[a]s a commodity, flexibility has multiple attributes such as capacity, ramp rate, duration and lead time among which there are complementarities." (Boscán and Poudineh, 2016: 2. These considerations complicate efforts to organise flexibility markets. As a Chatham House report stresses "[n]ew regulatory approaches are needed to encourage market actors to deliver flexibility..." (Froggatt and Quiggin, 2018: 3). Sure enough, Ofgem, the UK energy regulator, is "exploring how to support more large industrial and commercial customers to participate in providing flexibility..." (Ofgem, 2019)

On the other side of the equation, organisations that use or consume flexibility vary in how they combine the attributes of different flexibility 'products' and how and when these are mobilised (see, for example, Boscán and Poudineh, 2016: 8). Such representations conjure up the image of a flexibility consumer who can 'pick n mix' from a range of flexibility 'products' to create an optimal portfolio of options.

Abstracting flexibility from the conditions and social-temporal contexts in which it is constituted is a necessary step in establishing it as an identifiable commodity that can be traded in a market. In other words, the work of commodifying flexibility depends on holding many other features, of social life, and the energy system, stable (see MacKenzie et al., 2007). When treated in this way, flexibility,

like energy itself, comes to figure as a generic resource, the value of which depends on aggregate shifts in the timing of glut and scarcity in the supply-demand relationship.

This suggests that someone or something is responsible for the timing of demand and that flexibility can be ‘produced’ or generated at will. But who is this provider? How is flexibility generated, and who ‘owns’ it? Beyond these questions about the immediate market, it is clear that the value of flexibility is in some way related to longer term changes in provision and technology. As already mentioned, time and timing are increasingly important given the decline of coal (which can be stored) and the rise of renewables.³ A more subtle point is that the value of flexibility also relates to the existence of an uneven load profile. This leads to the more challenging suggestion that flexibility, here meaning the scope for modifying the timing of supply and demand, is woven into the broader spatiotemporal flexibility of society, and is itself an outcome of when and where people use energy.

In practice, these complications have yet to trouble the flexibility sector. This is in part because the ‘flexibility market’ revolves around a handful of methods and technologies, two of which we discuss below.

Operationalising flexibility: Storage and demand-side management

In energy policy and research it is common to list and evaluate the contributions that specific techniques might make to the project of enhancing ‘system flexibility’ or of delivering flexibility, here defined as a resource within the energy system. Such discussions often focus on the distinctive qualities of alternative flexibility instruments: for example, how much energy can be stored in a battery or a hydro system, and for how long? Alternatively, for how long can different energy demanding activities be deferred? Not surprisingly, issues of reliability are key. In this context, ‘solutions’ like extra storage, or automatic switching in which ‘passive’ loads are turned off at peak times,⁴ are likely to have the desired effect. By contrast, those that depend on the active involvement of consumers or providers are thought to be less predictable, and often less ‘valuable’ as a result.⁵ As detailed below, instruments of flexibility like storage and demand-side management affect different people and practices, and work in very different ways.

Storage

The capacity to store fuel for use at a later date is a common feature of energy systems, with examples ranging from small scale domestic wood stores, through to oil bunkers and gas-filled salt caverns. In contemporary debates about the UK energy system, there is increasing interest in whether storage systems might be able to deliver “... the flexibility needed to integrate renewable generation into electricity systems.” (Gissey et al., 2019: 685). Options include electrochemical (batteries), thermodynamic (storage heaters, boiler tanks), gravitational (hydropower), inertial

³ See also debates about the future role of natural gas in the UK’s energy networks e.g. McGlade, C., Pye, S., Ekins, P., Bradshaw, M. and Watson, J., 2018. The future role of natural gas in the UK: A bridge to nowhere?. *Energy policy*, 113: 454-465, and Hopley, A., 2019. Will gas be gone in the United Kingdom (UK) by 2050? An impact assessment of urban heat decarbonisation and low emission vehicle uptake on future UK energy system scenarios. *Renewable Energy*, 142: 695-705.

⁴ There are relevant distinctions between industrial, commercial, and domestic consumers, and the existence or not of financial incentives (tariffs) for switching consumption to off-peak times.

⁵ To be clear, we are not arguing that automated systems are in any sense ‘outside’ the realm of social practices or temporal organisation. The point is that they are designed around certain rules that fix meanings and responses in ways that more ‘persuasive’ strategies do not.

(flywheels), and conversion (electricity being used to make storable products such as hydrogen or methane). Since each form has particular qualities, multiple strategies are usually combined to enhance maximum output at a given time and to meet other criteria, including speed of response, anticipated lifespans, and costs of construction and operation (Newbery, 2018). Judgements about the optimal scale and form of storage usually depend on three metrics: the amount of 'surplus' renewable electricity supply available annually, the national variation in net demand across the day, and the national variation in net demand across a week. Apart from adjusting these figures for variations in weather (based on historical data), and estimating the anticipated uptake of specific technologies (e.g. electric vehicles), the extent of demand, and where and when it arises, are taken as read. This method is exemplified by a recent European Commission report on future energy storage (Andrey et al., 2019), and by numerous other industry documents including one produced by the Association for Decentralised Energy which states that:

“... Imperial College London research... found that up to 12.7GW of flexible DSM and storage technologies would be needed by 2030 to facilitate the penetration of renewable energy...”
(Association for Decentralised Energy, 2016: 13)

There are two points to highlight here. One is that the figure of 12.7 GW assumes existing patterns of consumption, tweaked to take account of changes in technology and population. This is odd in that demand is very unlikely to remain the same over the next decade, but it also makes sense in that it is only by holding a notion of 'need' stable that it is even possible to calculate the flexibility that additional forms of storage might afford.

Second, such estimates are layered on top of energy systems that are already replete with diverse forms of buffering and storage ranging from the hot water tank in the home to existing hydroelectric reservoirs. In practice, no one really knows how much storage exists, or therefore, how much flexibility the energy system might actually contain (Kaschub et al., 2016; Taylor et al., 2013). For those interested in whole systems energy management, what is known as decentralised storage is especially hard to calculate and impossible to control (Basak et al., 2012; Borne et al., 2018; Eid et al., 2016; Müller and Möst, 2018). In addition, exactly when and how so-called 'local' forms of storage are brought into play, and the significance of such systems is both uncertain and dynamic. At the same time, it is clear that past and present judgements about capacity and storage are closely tied to past and present judgements about needs and how these might be met. This is so whether the issue is that of sizing a hot water tank or a hydroelectric reservoir.

As these examples suggest, forms of storage and related estimates of flexibility are typically predicated upon more-or-less stable notions of socio-temporal organisation. More than that, and as discussed below, to treat storage as a response to the challenge of balancing supply and demand is to treat demand itself as a fixed and not a flexible part of the equation.

Demand-side management

On the face of it, methods of *demand-side management* (DSM) are more explicitly and more closely engaged with the detail of when energy is used, and what it is used for. These techniques include real-time pricing, automatic switching, and simply encouraging households or organisations to use energy at off-peak times. Given this variety, it is impossible to tell what is included, or what it really means to say that DSM can deliver up to 9.8GW of flexible capacity in the UK by 2020 (Association for Decentralised Energy, 2016). Industry estimates often distinguish between more reliable forms of industry-based DSM and the much more dispersed opportunities associated with individual households. For example, BEIS reports 1.4GW of DSM from industrial and commercial sources being

contracted in the December 2016 capacity auction with another 300MW purchased in the 2017 transitional arrangements auction as part of the Capacity Market (BEIS, 2018).⁶ Cutting across these complications, methods of calculating the significance of DSM usually depend on 1) estimating the impact of price on different end uses; 2) figuring out how much ‘negumption’ or non-consumption will be or could be delivered at any one moment in time, and 3) establishing which groups of consumers might provide it, and when. This latter factor is both critical and elusive. It is obvious that some people are likely to be more flexible than others and that some activities, like laundering, are more amenable to time shifting than, say, cooking or heating. Research into these forms of relative flexibility tends to consider individual activities in isolation, framing them as more-or-less discrete actions, unrelated to linked sequences or complexes of activity or to institutional rhythms, including working hours, school holidays, bus timetables, television programming, and so on (Powells et al., 2014). The significance of different timescales, such as weeks, months, seasons, and years is also out of the frame. More importantly, methods of demand-side management including ‘fit and forget’ automatic switching and efforts to encourage off peak demand overlook the deeper socio-temporal organisation of society, and the historical constitution of demand.

The Ironic Fixities of Flexibility

In summary, dominant discourses reify, commodify, and operationalise flexibility in ways that detach the timing of supply and demand from the socio-temporal organisation of society. As we have seen, all three representations of flexibility take present scales, forms, and levels of demand for granted. This is not to say that future visions do not anticipate changes in the types, timings, and levels of resource consumption, but when they do, such changes are considered in isolation from interconnected practices and social rhythms. As a result, established methods of operationalising or generating flexibility overlook 1) the co-constitutive relationship between supply and demand, and 2) the history and emergence of energy-demanding activity and when this occurs.

Since they do not anticipate societal or systemic change in what happens and when, and since they are also performative – that is, they are real in their effects – contemporary interpretations of flexibility have the paradoxical consequence of excluding the possibility of radically modifying the social rhythms of demand. More than that, because they justify and legitimise investment in technologies of certain size and capacity, they embed and materialise future expectations, based on current patterns of demand. This is what we mean when we refer to the ironic ‘fixities’ inscribed in strategies that purport to enhance flexibility in order to facilitate the rapid development and deployment of renewable energy.

Part 2: Re-Conceptualising Flexibility

In this second part of the paper, we leave energy sector discourses of flexibility behind and approach the topic anew. We do so by introducing and elaborating on the practical and theoretical consequences of conceptualising flexibility in a way that takes heed of ideas and insights from social theories of time and practice.

We argue that proponents of renewable energy and demand management would do well to consider flexibility not as something that can be provisionally fixed, manipulated, bought and sold, but instead, and following Latour (1993), as something that is made by beings and their relationships, practices and connections. From this point of view, flexibility is a central organising

⁶ For more on these auctions and arrangements, see the Electricity Market Reform Settlement Services Provider website: <https://www.emrsettlement.co.uk/about-emr/>

feature of social life and of how relations between supply and demand are constituted over the longer term.

Flexibility as an outcome of how social practices interconnect

We start with the simple contention that demand for energy is an outcome of the regular reproduction of what people do (Shove and Walker, 2014). From this point of view, energy demanding activity is in part made by and in part constitutes the temporal patterning of social life, along with related divisions of labour, locations and proximity of activities, and material arrangements. As new buildings, infrastructures, and physical spaces are developed, new activities, forms of association, and ways of living take hold. As the speed, sequence, frequency, duration, and synchronisation of what people do changes, so too does the temporal patterning of everyday life and hence the timing of energy demand.

At any one moment, social practices like commuting to work, cooking dinner, or having a shower have temporal features, including periodicity, sequence, synchronisation, duration and tempo, all of which matter for when they are enacted (Southerton, 2006). These features are, in part, constituted by the ways in which practices relate to each other. Engaging in one practice, like driving children to and from school may rule out others, giving a structure to the day and to the range of activities involved. These sorts of inter-practice relations play out across multiple temporal scales. For example, the temporalities of the school year overlap and intersect with others including shop opening hours and a multitude of institutional patterns including election cycles and events like Christmas (see for example Zerubavel, 1979; Shove, 2009; Southerton, 2013; Blue, 2017).

Aspects of these socio-temporal rhythms are embedded in and reproduced in material form. In the energy field, decisions and judgements about the sizing of infrastructures within the home and at the level of the national grid are, for instance, informed by judgements about how much energy people will use, and when (Shove et al., 2015). To give a very practical example, the size of a hot water tank relates to an assessment of how much hot water will be needed and the rate at which it can be replenished. Once in place, the size of the tank is in turn relevant for both the extent and the timing of bathing, washing, and hot water use. In Schatzki's terms, social-temporal-material configurations prefigure and restrict future adaptations and developments (Schatzki, 2010).

Since energy demand depends on the social-temporal organisation of daily life, it is inherently fluid, being continually reproduced and transformed as practices, their qualities, features, and connections intersect and change (Blue and Spurling, 2016). This does not mean that the extent and timing of energy demanding practices cannot be managed and steered, or that flexibility cannot be fostered. However, it is by now clear that this is not a question of operationalising storage technologies, or targeting groups of people, or practices, one at a time.

It is true that at any one point, some people and practices are more strongly or weakly connected than others, but it is wrong to treat flexibility as a property or quality of those people or practices. Instead, and as Shove and Cass explain:

“... flexible practices are those that are relatively detached (they are not tied to specific times or places); de-coupled (not requiring the co-presence of other things or people), or capable of being interrupted, restarted and broken into smaller parts).” (2018: 9)

In this analysis, whether laundry is more flexible than cooking, or whether the retired are more flexible than those who work depends on forms of detachment, decoupling, and interruptability that are themselves outcomes of how multiple practices affect each other and how these interactions are

reproduced and changed over time. These relations are not haphazard or random and in the next section we expand on the significance of two modes of interconnection that are especially relevant for our understanding of flexibility. These are sequence and synchronisation.

Sequence

In practice-theoretical terms, sequence has to do with the ways in which practices precede or follow each other. Sometimes connections are closely coupled, resulting in what look like forms of temporal immediacy: for example, commuting typically happens right before and right after working. Others involve periods of deferral and delay: for example laundry is piled up before the washing is done, and wet laundry then takes time to dry. These features are important in that "... the potential for rearranging daily schedules depends on how different practices connect to each other, and on the sequences or chains of action involved." (Shove and Cass, 2018: 7)

Some sequences are linked to series of material transformations. As already mentioned, washing, drying, and ironing clothes depends, at each stage, on a pile of dirty, or wet, or creased clothes. In this case, as with shopping, cooking, and eating, sequences are held in place because "inputs to one practice are transformed into outputs that may become inputs of another practice" (Hui 2017: 62). Not all sequencing is so obvious. In a study designed to identify what Mattioli et al. call 'car dependent practices' (2016) time use data was used to identify activities that came before and that followed the use of the car. From this, it was possible to see how car travel was embedded in specific chains of action, including those surrounding transporting children to school, going shopping, and walking the dog. As this research demonstrates, sequences are hugely important for the timing of domestic energy and mobility demand.

In theory, rhythms of practice, and of energy demand, might be reconfigured by disrupting these steps: for instance by removing or outsourcing some link in the chain; by interrupting previously seamless processes, or by modifying the material relations involved. However, this is to suppose that sequences can be adjusted one by one. Instead, and as Durand-Daubin's (2016) work on French and British meal times demonstrates sequences are defined and shaped by other forms of socio-temporal organisation. Preparing food comes before eating it and washing up, but the timing of breakfast, lunch and dinner is also a matter of social convention, including the habit of eating together as a family. That is to say that sequences are synchronised (interconnected with other chains of activity) in ways that uphold and reproduce cultural conventions about when different practices take place, and with whom.

Synchronisation

Synchronisation refers to the coming together of multiple people or practices at the same spatiotemporal location. Meal times are the classic example, punctuating the day and representing relatively 'fixed' events around which others are organised. Other forms of synchronisation are held in place by institutional arrangements such as the 9am – 5pm working day, bank holidays, and the structuring of the school year. The expectation that many people will start work at 9 am underpins what is known as the 'rush hour', a period which often extends to several hours during which very large numbers of people and vehicles are on the road at the same time (Cass and Faulconbridge, 2016). Infrastructures, whether of transport or of energy provision, are typically sized and designed to cater for these 'peaks'. This means that they are also 'over sized' at other times of day, or year.

This has inspired renewed interest in identifying practices that are more or less 'synchronised', usually on the grounds that it might be 'easier' to shift those that are not so strongly tied to a given time and location in daily schedules. van Tienoven et al. (2017) have, for example, sought to

measure the degree of stability certain activities have in relation to given 'time-slots'. Perhaps not surprisingly, they find that sleep and paid work are the most stable and also the most synchronised of the practices they considered (see also Anderson 2016 and Torriti 2017).

However, it is misleading to view the socio-temporal positioning of practices in isolation. This is evident in Blue's (2018) study of peak energy demand in hospitals. As described, peaks are, in part, an outcome of the timing of operating schedules and supporting services, held in place by the totality of hospital activities and by organisational features including job roles, medical protocols, and patient centred sequences of sleeping, eating, and medication. As with sequences, forms of synchronisation are constituted by a myriad of other interconnected practices.

Flexibility is an Emergent Feature of Complexes of Practices

In describing these multiple temporalities, our aim is to underline the point that time slots, whether defined by sequences or forms of synchronisation, are not given but are the emergent outcomes of multiple interactions and interconnections between practices. This insight points us toward a more comprehensive conceptualisation of flexibility, and of how temporal rhythms develop and change. Sequencing and synchronising are not the only routes through which practices connect in time and space. Forms of competition are also relevant, as are sometimes critical issues of duration, and frequency.

The discourses of flexibility that run through the energy sector take no account of how the temporal 'texture' of society changes. However, this is an important topic for those who write about time and society. For example, some authors contend that there has been a 'softening', 'flexing', and 'fragmenting' of how people and things interact in time and space (see Hubers et al., 2008). There are arguably fewer 'institutionally timed' events than there were a few decades ago and this, together with trends in online shopping, snacking, travel and flexible working, on-demand TV and longer opening hours points to a systemic shift in how practices hang together. The processes involved are complicated and interwoven, meaning that more and less stable forms co-exist. For example, while meal times have remained largely the same over the last fifty years (Yates and Warde, 2016), what lunch is, where it happens and with whom have changed radically. For example, in 1937, in the UK, it was common to return home for lunch in the middle of the day. Southerton points to the de-institutionalisation of many times (including work times, shopping times, meal times, and laundry times) that has produced "a wider variety and greater flexibility of temporal rhythms in everyday life", and the resulting disappearance of lunch-at-home (2009: 62). In reflecting on these processes, and the forms of interdependence involved, our aim is to show that it is both possible and plausible to conceptualise flexibility as an emergent feature of past and present social-temporal configurations of practices and of related processes of prefiguring and change/stability.

At this juncture, readers might expect us to bring the first and second parts of the paper together, and to explain what a practice theoretically informed approach might add to contemporary understandings of flexibility in the energy sector. However, we contend that these positions are ontologically incommensurable. Instead of building on or contributing to representations of flexibility in the energy sector, we have taken a different path, defining flexibility in a way that demands serious engagement with the temporal organisation of social life. That does not mean the position developed here is of no relevance to debates about energy and demand. Far from it. However, it does have a number of far reaching consequences: calling for a more subtle and also a more historical understanding of the multiple temporalities of energy supply and demand, and radically expanding the range of organisations and actors that have a hand in shaping and changing the temporalities of demand. This is clearly not just an issue for the energy sector alone.

Conclusions and implications

We have argued that social theories of time and practice provide the basis for reconceptualising flexibility. Rather than thinking of flexibility as a feature of whole energy systems, as a commodity, or a property of specific groups of people or practices, we take it to be an emergent outcome of the historical development of constellations of practices that make up social life. In this final section we comment on three particularly important implications of this approach for the ambition of establishing socio-temporal rhythms and patterns of demand that are, in our terms, more flexible, and potentially more compatible with a radically decarbonised energy system.

Implication 1: The timing of supply and demand matter for each other

The first is that, in the long run, supply and demand matter for each other. By implication, whole system approaches really do need to consider *whole* systems. This means recognising the co-constitution of both demand and supply. Rather than viewing present patterns of demand as fixed, non-negotiable conditions, and rather than thinking of flexibility instruments (storage, DSM, time-related pricing, etc.) as if these were independent of the constitution of need, energy researchers and policymakers could and should take advantage of the fact that forms of provision are integral to, and not outside of, the practices they enable, and to when and where these occur. Linked to this, previous infrastructural interventions have histories and consequences that are themselves embedded in present configurations of practice. In other words, it is not simply that the timing of supply and demand matter for each other. This relation is ongoing; it has a history and is continually in flux. As a result, interventions do not happen in the abstract, or on a 'blank' canvas: they add to and become part of the long term co-development of infrastructures, institutions, and complexes of social practice.

Implication 2: Representations of flexibility are performative and have the potential to strengthen and weaken societal rhythms

A second implication is that representations of flexibility have effect. The reified, commodified, and operationalised interpretations of flexibility that we have described are not neutral. As we have explained, contemporary techno-economic responses reproduce current and fixed interpretations of need and therefore maintain, reproduce, and strengthen certain connections between practices. As a result, and despite the stated intention, measures to increase flexibility in the energy sector are very likely to have the reverse effect. By perpetuating current relations and arrangements, they help maintain, rather than challenge or reconfigure the socio-temporal patterning of what people do. Infrastructures and systems of provision and pricing do not determine the extent and the timing of demand, but decisions about the sizing of systems, including forms of storage and distinctions between flexible and inflexible or non-negotiable demands, are real in their effects. In this context, holding fast to a commitment to developing “demand-side resources for system balancing to enhance system flexibility *without compromising the service quality delivered to end customers*” (Shakoor et al., 2017: 10 italics added) is telling in its own right. In contrast, we argue for methods of enhancing whole system flexibility that include and that explicitly engage with the scope for redefining meanings of service and quality.

Implication 3: Fostering flexible futures

Bringing these two points together, a third implication is that better understanding how social practices link together in time; how these connections define the contemporary temporalities of supply and demand, and the scope for reconfiguring such relations, is a necessary but so far missing piece of the carbon reduction 'jigsaw'. Making markets for flexibility, much more narrowly defined,

does not help and may actually hinder this ambition. So what are the alternatives? How might policymakers, regulators, and the sector-as-a-whole actively foster 'genuinely' flexible futures?

Since this is not a new question, historical experience and cross-cultural comparison provide good examples of quite different social-temporal configurations that are also linked to technologies, infrastructures, and to related forms and patterns of consumption and practice. Contemporary industrial societies rely on different energy sources to flatten out seasonal variations in heat and light, thereby enabling social practices to hang together in ways that are not massively different in summer, as compared with winter. But it is, in theory, possible to imagine future ways of living that are normal, and valued, and more closely matched to annual cycles, and to the availability of different forms of renewable power. As cultural histories of time (Zerubavel, 1981; Zerubavel, 1982; Zerubavel, 1985) demonstrate, there are many ways in which social practices can be sequenced and scheduled and the patterns we are accustomed to today are unlikely to remain the same forever. Although it might be read this way, this is not a backwards-looking conclusion. Instead, it is a conclusion that argues for a much wider recognition and debate about the significance of temporal organisation for future energy systems and carbon reduction (and vice versa).

This is not a task for energy researchers alone. One reason for writing this article, and for submitting it to *Time and Society* is to alert a broader audience to the importance of time and timing for the emergence of a lower carbon society. Although we have focused here on the currently important topic of flexibility, the forms of representation and intervention that we have discussed are symptomatic of a much wider failure - especially within engineering and economics - to engage with insights from the social sciences. The present position is also symptomatic of another failure, this time within the social sciences, to unpack, demonstrate, and argue for the practical significance of a thoroughly historical, thoroughly social understanding of how temporalities are constituted and how they change. This cannot be fixed with one article alone, but with this contribution, we hope to have given a sense both of the potential for situating 'time' as a central concept in energy research, and for social theorists of practice and of time to make a really significant contribution to this agenda.

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