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## **Flexibilities in Energy Supply and Demand: Legacies and Lessons from the Past**

### **Abstract**

The goal of maintaining current levels of energy supply and demand whilst reducing their carbon intensity will require greater use of renewables. As a result, new forms of flexibility will be needed. While the emerging “flexibility industry” promises solutions based on current configurations, this collection shows that the problem of managing fluctuations in the relation between supply demand is not new. The papers included in this special issue work with different approaches and scales of analysis, but all show that lessons for balancing energy supply and demand today can be drawn from the past. Just as important, they show that the legacies of past practices and infrastructures live on and have effect in contemporary energy systems.

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### **Plan of the article**

- Introduction
- Flexibility is multiple, dispersed and emergent
- Flexibility is a product of interconnected energy systems and their histories
- Flexibility is positioned at the intersection of supply and demand
- Flexibility is a feature of service provision
- Flexibility is a feature of how energy is distributed in space and time
- Legacies and lessons

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## INTRODUCTION

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- 1 Flexibility has emerged as a central concern and as an increasingly important concept for governments and institutions committed to the project of rapidly decarbonising energy systems.<sup>1</sup> This makes sense: if the goal is to reduce the carbon intensity of energy networks while maintaining present levels of energy supply and demand, there is no option but to make much greater use of more renewable sources of energy (e.g. wind, solar, tidal power). Since patterns of generation are intermittent (following seasonal or diurnal cycles, including tidal flow), new forms of flexibility are needed to keep supply and demand in balance.
  
- 2 These challenges have created opportunities for what is known as the “flexibility industry”, and for organisations promising to help utilities “... respond rapidly to large fluctuations in demand and supply, both scheduled and unforeseen variations and events, ramping down production when demand decreases, and upwards when it increases.”<sup>2</sup> Decarbonisation implies greater flexibility across the energy system as a whole, and a range of interventions and solutions are proposed, some of which are more relevant to gas (which is easier to store) than to electricity. These include commodifying non-consumption, paying businesses and organisations to shed or reduce consumption when demand is high, and/or encouraging fuel switching to balance loads. In the residential sector, tariffs, price signals, and other sorts of information, including data on carbon emissions

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<sup>1</sup> See, for example, Ofgem, “Upgrading our Energy System: Smart Systems and Flexibility Plan” (HM Government, UK, 2017). <https://www.ofgem.gov.uk/publications-and-updates/upgrading-our-energy-system-smart-systems-and-flexibility-plan>. Stéphane Goutte, Philippe Vassilopoulos, “The Value of Flexibility in Power Markets”, *Energy Policy*, vol. 125, 2019, 347-357. Eric Martinot, “Grid Integration of Renewable Energy: Flexibility, Innovation, and Experience”, *Annual Review of Environment and Resources*, vol. 41, 2016.

<sup>2</sup> International Energy Agency, *Empowering Variable Renewables: Options for Flexible Electricity Systems* (Paris: IEA, 2008), 14. [https://www.iea.org/publications/freepublications/publication/Empowering\\_Variable\\_Renewables.pdf](https://www.iea.org/publications/freepublications/publication/Empowering_Variable_Renewables.pdf)

are designed to encourage consumers to change the timing of what they do and to use electricity during off-peak hours. On the supply side, various strategies are adopted including “packing” gas into the network and ramping up electricity supply to cope with peaks in demand.

As one might expect there are different ways of conceptualising flexibility.<sup>3</sup> Is it a feature of “whole” energy systems? Is it a commodity (being bought and sold as a means of balancing supply and demand)? Is it a term that describes strategies for demand side management? Does it refer to an individual or organisational capacity to “flex”? Or is it best understood as a feature of how social relations and rhythms of production and consumption are entangled? Whatever the response, there is a tendency to think of flexibility as a new problem. Rather than tracing the history of the concept of flexibility, and rather than supposing that there could be one such narrative, the papers in this collection show that the problem of balancing supply and demand has been formulated, understood, and acted on in different ways and at different scales in particular times and places.

In putting this special issue together one aim is to draw lessons from the past and to enrich and inform the ways in which flexibility is understood today. In taking this agenda forward, contributors bring the insights of historical research to bear on contemporary social, technical, economic, and political questions about energy supply and demand. In doing so they make use of concepts from social theory – for example, emphasising the layering of infrastructural and institutional relations; the recursive dynamics of supply and demand, and the salience of “scale” for the analysis of more and less flexible configurations. This combination of approaches is consistent with our second aim which is to foster interdisciplinary exchange between historians and social scientists as a means of revealing the legacies of

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<sup>3</sup> Stanley Blue, Elizabeth Shove, Peter Forman, “Conceptualising Flexibility: Challenging Representations of Time and Society in the Energy Sector”, *Time & Society*, vol. 29 n° 4, 2020.

previous policies, strategies, and practices for present systems and infrastructures of provision.

- 5 Although some authors are historians by training, others have backgrounds in sociology, engineering, geography, and science and technology studies. This is relevant for how contributors approach, conceptualise, and make use of historical material. Other differences have to do with the spatial scale of analysis. For example, Shaw, Moss and Sareen, and Hatton-Proulx describe infrastructural relations within cities. By contrast, Silvast and Abram report on the details of network management as that is enacted in gas and electricity control rooms. There are also differences in the time scales across which these studies extend. For example, some contributions describe the development of infrastructures (and related patterns of demand) over several decades (Hatton-Proulx; Moss and Sareen); others select a series of revealing turning points (Shaw) and phases (Forman), or zoom in on one moment in time (Fell). In their different ways, all these strategies shed light on the challenges of managing supply and demand, and on how these have been understood and handled in different settings.
- 6 The result is a collection that reveals the multiple and layered socio-material-political geographies of energy systems and the various flexibilities that they afford and enable. It shows how material legacies (in the form of infrastructures and networks) are intertwined with ideological legacies; with embedded assumptions and interpretations of consumers, markets and control, and with the fluctuating sociotemporal rhythms of both supply and demand. More specifically this special issue shows how the balance and the mix of consumption and provision has been thought about and how these schools of thought persist and change.
- 7 The rest of this introduction maps out the themes that link these papers together, and highlights the conclusions and insights arising from this novel conjunction of methods, sites, and units of analysis and enquiry.

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## **FLEXIBILITY IS MULTIPLE, DISPERSED AND EMERGENT**

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Rob Shaw's paper on "polyflexibility" introduces a range of ideas that also frame the collection as a whole. Inspired by Lefebvre's rhythm analysis, Shaw writes about how different kinds of flexibilities constructively and destructively interact with one another. In taking this approach he suggests that what constitutes flexibility at a given time, and in a particular place, is an outcome of how financial, political, technological, social, and legal assemblages combine. 8

These effects and processes are revealed via a careful analysis of public lighting in Newcastle-upon-Tyne in the UK. In detail, Shaw describes the "modalities" (of governance, infrastructure, finance) that characterise the gradual introduction of electric lighting; the management of lighting during the Second World War, and the phasing in of LED (responsive) lighting (today). 9

Drawing on documents and reports produced by the Eastern Electricity Supply company, the Newcastle Lighting Committee, the City Police, and local newspapers, Shaw describes how the interests of various parties not only matter in moments of transition, but have effect on and shape the future capacities of each other all the time. As this study shows, and as other contributors demonstrate, the possibilities of the present (in this case, the scope for adopting smart, agile, and responsive LED public lighting) are defined by the material, ideological, and institutional "legacies" of previous configurations. 10

More importantly, the notion of polyflexibility recognises that flexibility is not singular, and not a property of a given service, system, or person. Rather, it is dispersed and emergent, dependent on and contributing to the unfolding of possible historical interactions and, the capabilities of related modalities. The articles included in the rest of the special issue explore different aspects of this multiplicity, starting with a discussion of how changes in the domestic use of gas matter for the timing of demand and the development of gas networks in the UK. 11

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### **FLEXIBILITY IS A PRODUCT OF INTERCONNECTED ENERGY SYSTEMS AND THEIR HISTORIES**

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12 The fact that gas can be stored does not undermine the importance of balancing supply and demand in real time. Forman works with selected material from the UK's National Gas Archives to show that the practicalities of managing this relation depend on what gas is used for, and as a result, when demand occurs. When gas was mostly used for lighting, peaks occurred at night and during the winter. When it was used not only for lighting, but for cooking and/or for industrial manufacturing new rhythms of demand came into play that required different networks and arrangements of provision. Now that gas is predominantly used for heating, seasonal fluctuations are much more important than variation through the day. The first point that this paper makes is that these changes depend on a two-way street. This is obvious in Forman's description of how utilities have responded, and in how changing patterns and temporalities of demand figure in the design and management of the gas network as a whole. A second insight is that the material and institutional organisation of gas cannot be seen in isolation: the shift from one dominant end use to another relates to the positioning of gas alongside other fuels, including electricity. These conclusions underline the point that the flexibility of a given fuel is a relational and not an essential property. More specifically, it depends on what any one energy source is used for not in the abstract, but alongside coexisting fuels, technologies, and everyday practices.

13 Contemporary debates about flexibility and decarbonisation tend to focus on when and how the timing of electricity demand might need to "flex" in order to accommodate more renewable but intermittent supply. The place of gas, and indeed other fuels, is missing from this debate, as is an understanding of the historical legacy of different systems and scales of provision – all of which are, in turn, related to changing patterns of end use and thus demand. Recognising these complexities takes us deeper into themes of modality and assemblage, as introduced by

Shaw. The next two papers also consider the effects and legacies of different modalities within an energy system or assemblage, but do so by focusing specifically on different spatial scales: an energy utility and a city respectively.

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### **FLEXIBILITY IS POSITIONED AT THE INTERSECTION OF SUPPLY AND DEMAND**

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Hatton-Proulx's history of Montréal Light, Heat and Power shows how the ebb and flow of demand and supply in Montréal have been managed by just one monopoly supplier in the time between the First World War and the Great Depression. This work complicates more familiar narratives of endless growth, revealing significant fluctuations within energy systems, including moves back and forth between fuels and between "modern" (networked) and "traditional" systems like heating with wood. In characterising these "stop-go" patterns, this paper distinguishes between fluctuations that are, at different times, primarily associated with provision on the one hand, or consumption on the other. 14

By zooming in on a particular location and utility, Hatton-Proulx reveals the detail of changes and fluctuations in the balancing of energy supply and demand, and their volatility, including the effects of major changes in demand associated with the First World War and the Great Depression. As represented here, different forms of flexibility arise as a consequence of the asymmetric and contingent relationship between supply and demand. Although aspects of this case are specific to the location, this paper points to the fact that the challenge of handling intermittency, gaps, and major fluctuations is an unavoidable aspect of making and managing networked infrastructures. 15

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### **FLEXIBILITY IS AN OUTCOME OF POLITICAL AND INSTITUTIONAL ARRANGEMENTS**

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Moss and Sareen also write about the reconfiguring of supply and demand, this time focusing on developments in one city (Berlin) over a hundred year period. These authors use archival 16

material and secondary literature to identify and describe the social, political, and economic events that have shaped Berlin's energy systems since 1920.

- 17 Much of their description has to do with the spatial organisation of supply and the impact this has on methods adopted to balance loads “locally”. More specifically, Moss and Sareen describe the gradual erosion of material arrangements born of an “insistence” on the local production of town gas and electricity. As they explain, the details of infrastructural systems – their size, siting, and capacity – are products of a complex history of political decisions and circumstances, including sometimes spectacular dips in the demand for different fuels. These legacies, inseparable from dramatic upheavals in East and West Berlin, and in the city's unification, have a tangible impact on present patterns of provision.
- 18 The point is not simply that current possibilities, and current flexibilities (or inflexibilities) are outcomes of the social, political, and material “layering” of infrastructures. While this is one important conclusion, the study of Berlin underlines the extent to which systems of provision in any one location are (and are not) entangled with networks that extend across much larger spatial scales. Given that the interweaving of urban and extra-urban relations is inseparable from the histories of the places involved, flexibility is, in this account, a product of the intersection of quite specific material, institutional, and ideological legacies.

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### **FLEXIBILITY IS A FEATURE OF SERVICE PROVISION**

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- 19 The prospect of selling heat-as-a-service (that is, selling certain levels of domestic heating for a fixed price, rather than selling gas or electricity) is currently discussed as a potential solution that allows energy suppliers to meet heating requirements in the most cost effective and carbon efficient way possible. This is not a new idea and in his paper Fell revisits “Budget

Warmth”, a heat-as-a service, commercial tariff introduced in the UK during the 1980s.

Fell's review of industry journals and government reports, alongside an interview with a key informant formerly working at the Electricity Council, reveals some of the tensions that prevented widespread uptake of this scheme. These included consumers' sense of being “out of control”; combined with a reluctance to sign up to long term contracts of the kind that providers needed if they were to recoup their costs. To complicate matters, methods of measuring domestic energy use (in the form of heat) were not precise enough at the time to enable providers to modify the timing of provision and thereby benefit financially from the capacity to control domestic load.

This one case reveals the importance of an historical understanding of previous “successes” and “failures” but not in the way that one might expect. As Fell describes, the specificities of context and setting are massively important for the fate of schemes like “Budget Warmth”. This makes sense, but it also confounds attempts to extract and apply lessons from the experiences of the 1980s to the present day. Instead, the more important point is that consumers' expectations (for example of controllable, instantly adjustable temperatures) are not separable from prevalent systems of provision, including the sizing and design of energy supplies and heating technologies. In other words, interventions such as Budget Warmth have effect (or not) within and as part of a system of expectations and technologies that is constantly in motion.

The contributions from Forman, Hatton-Proulx, Moss and Sareen, and Fell shed light on aspects of what Shaw conceptualises as polyflexible socio-material assemblages. Despite taking different angles, and despite working across different historical periods and with diverse materials, these authors describe flexibilities as these are constituted at the intersection of multiple modalities – of governance, infrastructure, and finance. In bringing these threads together,

the final paper in the collection takes a closer look at how contemporary methods of handling fluctuations in the supply-demand relation are shaped by material and ideological legacies, and by networks that have been built, adapted and repurposed over the years.

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### **FLEXIBILITY IS A FEATURE OF HOW ENERGY IS DISTRIBUTED IN SPACE AND TIME**

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23 Silvast and Abram's ethnographic study of what engineers and control room operators do and how their work is organised shows how multiple histories of the sort explored in the other papers in this special issue intersect and combine. This study, which involved observations of gas and electricity control rooms in the North of England (in 2019), oral histories, and an analysis of trade and technical journals, provides a compelling account of the layering of sociotechnical systems of mixed vintage, and of how past infrastructures define the limits and possibilities of flexibility today. In addition, and as Silvast and Abram explain, methods of network management have histories of their own. These are reproduced in the embodied knowledge of engineers, in the experiences they accumulate, and in the changing challenges of balancing supply and demand in real time.

24 These come together in the control room, and in the training and "culture" of the various occupational groups involved in maintaining networks and in managing the energy that flows through them. None of these aspects is stable. For example, as new equipment is installed and as skills in predicting and forecasting demand become more important, other forms of expertise (including that of managing so-called "legacy" assets) becomes redundant. Similarly, as the features of the network change, the function of the control room, and the scope for making adjustments to accommodate fluctuations in supply and demand, change as well.

25 When viewed in this way, the work of control room operators provides unrivalled insight into how technologies and skills shape each other, and into how these relations unfold over time.

Just as important, it shows how past rationales and the forms of infrastructural investment associated with them inform current ambitions and programmes of reinforcement and renewal.

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### **LEGACIES AND LESSONS**

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26 There is some truth to the claim that patterns of flexibility are defined by the historical development of infrastructures and by related patterns of demand. Existing energy systems have features (size, capacity, interdependence) that are important for how they are managed and controlled, and for how easy they are to "flex" and adapt. This is something that policy makers would do well to remember.

27 That is one interpretation, and that is one way of reading the papers we have gathered here. However, there are other ways of thinking about the contemporary relevance of the past. In treating energy systems as entangled and dynamic combinations of physical, ideological, and institutional arrangements, contributors to this collection treat them as "assemblages" that are continually in motion. From this perspective it is impossible to pin down or systematically trace the origins or "sources" of contemporary flexibility. Flexibility is, instead, conceptualised as an outcome of the changing *relation* between supply and demand, and of intersecting formations of legal, financial, social, governmental, and technical modalities.

28 That is to say that past modalities live on, and have effect in, present arrangements. This is in keeping with Schatzki's conclusion that past everyday practices and the infrastructural arrangements of which they are a part do not just prefigure but continue to exert their presence on current configurations:

"...the past is present in pushing or carrying across the alleged gap or boundary between it and the present, present events dropping "like ... over-ripe fruit[s]" as the past presses into the future. These conceptions thus hold that the gap between past and present is an illusion. The past is *in* the present. It has not

fallen away behind the present, consigned to inertness, irrelevance, or inexistence.”<sup>4</sup>

29 The suggestion that past configurations have effect *within* and as part of contemporary conventions and understandings of normal practice has implications for the status of historical analysis. From this point of view, the legacy of historical arrangements is reproduced in the present, and in how layers of infrastructure and expectation prefigure and restrict future interpretations of limits and possibilities in supply as well as in demand.

30 This argues for a distinctive role for historical research. When faced with the need to rapidly decarbonise and thus increase the flexibility of the energy system as a whole, policy makers would do well to take note of the *dynamic*

processes in play and of the longer and shorter-term “trends” of which present configurations are made. In this context, the contribution is not so much that of explaining how existing infrastructures come to be as they are. Rather it is a matter of better understanding the sorts of relations and tensions that animate ebbs and flows in supply and demand. As the articles in this collection demonstrate, the flexibility of a given service, source, system, or demand is never absolute. Instead it is always extended, relational, and multiply interwoven.

Capturing these connections calls for combinations of theory and method and for styles of enquiry that are not the province of sociology, or of history alone. This collection gives a taste of what such hybrid studies have to offer. 31

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<sup>4</sup> Theodore R Schatzki, *The Timespace of Human Activity: On Performance, Society, and History as Indeterminate Teleological Events* (Plymouth, UK., Lexington Books, 2020).

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