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Polyflexibility in Public Lighting

Abstract
This article introduces the concept of 'Polyflexibility' as a way of expressing the complexity of interacting forms of flexibility. The term, deriving from Henri Lefebvre's concept of polyrhythmia, is used in contrast to conceptualizations of flexibility in energy studies which rest primarily on locating flexibility in either supply or demand. By focusing on the Polyflexibility of an energy system as a whole, we can better identify when, how and why certain systems have been flexible or inflexible. This is illustrated through a study of the different relationships between financial, political, technological, social, legal and other modalities at three moments of transition with public light in Newcastle-upon-Tyne, UK: the start of the transition from gas to electric lighting (1890-1907); the blackout period of World War Two (1938-1946); and the contemporary transition from sodium-vapour to LED (2012-).

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1 In the realm of public lighting, a promise has emerged since the early 2010s. This promise is that new, smart lighting systems drawing from LED lighting technology will be able to respond in real-time to the demands of the users of public spaces. The reward, we are told, is reduced energy use which in turn translates into: lower carbon emissions; reduced light pollution; and less public expenditure on lighting. The confidence in this future, for example, can be seen in the engineering, planning and design firm Arup's 2015 publication *Cities Alive: Rethinking Shapes of Night* in which "Rapid advances in lighting, information technology and intelligent systems offer immense opportunities for radical new approaches to urban night-times".[1] This vision of smart and LED lighting offers the *capacity* for significant changes in public lighting regimes, most centrally surrounding the flexibility of public lighting infrastructure. The smartest of such smart lighting systems are currently confined to experiments, pilots and showcase installations, offering developer-curated insights into possible future urban nightscapes. In wider cities, the implementation of smart lighting is underway but is more tentative. Local authorities introduce technologies into already-operating infrastructures, legal frameworks, political contexts and budgetary restraints, all of which shape the reality of technological change. In other words, "technologies and their institutional and social settings co-evolve"[2], as path-dependent moments in which existing social, economic and governmental-institutional settings intersect with the materiality of both existing and new technologies.

2 In this paper, I want to historicize the contemporary transition in public lighting with reference to some of its predecessors, using the city of Newcastle-upon-Tyne in the UK for my case study. Newcastle is of interest as a notable city in the history of lighting: the first public display of an incandescent lightbulb occurred on 3rd February 1879 in Newcastle, produced by local engineer Joseph Swan;[3] subsequently, Swan created the first – experimental – public electric lighting in the world on Moseley Street, and lit the first known private home to have full electric lighting installed, Cragside, the rural mansion of local businessman William Armstrong.[4] As well as the contemporary transition towards greater use of LED and smart lighting technologies (focusing on the period since 2012), two further moments of transition in Newcastle's lighting history are chosen. The first covers the period of experimentation associated with the first widespread use of electric public electric lights (1890-1907); and the second covers the rapid transition into and out of the World War Two blackout restrictions (1938-1946). The paper draws from archival material held by the Tyne and Wear Archives & Museums (TWAM) for the first two periods, and from qualitative interviews and the analysis of contemporary policy documents for the latter period.

3 In looking at these moments, I want to show how flexibility – and fixity – have been dependent upon the particular relationship between technology, institution and investment. In other words, what is fixed and what is flexible have not been consistent, but have been dependent upon the public lighting assemblage at the time and place of transition. In so doing, I present flexibility not as a characteristic of either demand-side usage or supply-side provision, but as an emergent characteristic of the energy assemblage as a whole. To make this argument, I use the term *polyflexibility* to draw attention to this conceptualization of flexibility as emergent from the intersection of the flexibility of multiple different actors, rather than as a single characteristic. Polyflexibility is a way of describing a relational flexibility, that is, a flexibility which is dependent upon how different actors relate. The term is lifted from Lefebvre's description of

1 Arup, *Cities Alive: Rethinking the Shades of Night* (London: Arup, 2015), 65

2 Charlie Wilson and Arnulf Grubler, "Lessons from the History of Technological Change for Clean Energy Scenarios and Policies", *Natural Resources Forum,* vol. 35, n° 1, 2011, 165.

3 Ralph Clark Chirnside, "Sir Joseph Swan and the Invention of the Electric Lamp", *Electronics and Power*, vol. 25, n° 2, 1979, 98.

4 *Ibid*., 100.

polyrhythms in his book *Rhythmanalysis*,[5] which explores what he sees as the dialectic relationship between ever-expanding capitalism, and everyday embodied temporalities. This helps express the way in which flexibility is a result of changing, evolving and contextual power relations between distinct actors.

THE PROMISE OF TRANSITION IN SMART LIGHTING SYSTEMS

4 Street-lighting management has, since it evolved as a city-wide process toward the end of the eighteenth century, involved a certain amount of temporal planning and organisation. In a well-known account, Schivelbusch describes a lighting schedule for early nineteenth century Paris, revealing a detailed plan for lighting shaped by the diurnal cycle of light and dark, as well as public rhythms: for example, no public lighting was to be provided on Christmas Day.[6] Similar levels of this planning and management occurred in the UK: in 1896, the 'Newcastle-upon-Tyne Corporation Street-Light Sub-Committee' (hereafter: Newcastle Lighting Committee) researched the different times at which British cities operated their street-lights on a month-by-month basis. Their research revealed wide variation in hours of lighting from 3408 hours a year in Leicester and 4313 hours a year in Newcastle. The differences could not be explained by latitude: at mid-summer, Newcastle provided more public lighting than many cities to its south. They also discovered complex local lighting practices; in Edinburgh, it was reported that "care has been taken to put alternate lamps on separate circuits in all streets... [this] allows half the lamps to be switched off at or about midnight, still leaving the streets well lighted"[7]. Here in the late nineteenth century we see practices which attempted to offer something similar to the new promises of smart lighting, namely, varied lighting levels according to predicted demand, at the most efficient cost. Temporal coordination has thus long been part of street-lighting, and the idea of coordinating with both natural lighting levels and anticipated demand is not new.

5 What is potentially new with smart lighting is the extent, depth and sophistication of this planning and coordination. Smart lighting draws on three primary technologies. The first is LED lighting, which while not inherently smart, is the form of public lighting most suitable for integrating into smart systems. LED lighting can be switched on and off quickly, and can be set to different levels of brightness. Furthermore, it produces a more condensed and focused light than the diffuse lighting of the most common pre-existing public lighting source, electric sodium lamps. All of these mean that in designing a smart lighting system, which gains its potential efficiency from this technological flexibility, LED lighting is necessary.[8] Second (and third) are the two technologies used to make this LED lighting 'smart'. Smart lighting can operate either, or both, through the forecasting of demand, or through real-time responses to demand, that is, through sensors which identify users of cities being present. Smart technology which uses forecasting and sensors together is the most powerful, allowing lighting to be programmed in anticipation of demand created by particular events, traffic conditions and the weather, and integrating this with real-time data about the city. Researchers anticipate possible savings of 30-50% of energy if neural networks are used to predict demand, in comparison to lighting provided without any anticipatory procedure.[9],[10] Using only sensor-technology is a simpler but cheaper approach, with lighting either off or at lower levels, until sensors identify that lighting is required. Such systems will switch on according

5 Henri Lefebvre, *Rhythmanalysis: Space, Time and Everyday Life* (London: Continuum, 2004 [1992]).

6 Wolfgang Schivelbusch, *Disenchanted Night* (Oxford: Berg Publishers, 1988), 91

7 Report to Newcastle Lighting Committee, 7 December 1896. Tyne and Wear Museums and Archives (TWAM).

8 Miguel Castro et al., "Smart Lighting Solutions for Smart Cities", in *Proceedings of the 27th International Conference on Advanced Information Networking and Applications Workshops* (Institute of Electrical and Electronics Engineers, 2013), 1374-1379.

9 Stefano Pizzuti *et al.*, "Smart Street Lighting Management", *Energy Efficiency*, vol. 6, n° 1, 2013, 614.

10 Francesco Marino *et al.*, "Adaptive Street Lighting Predictive Control", *Energy Procedia*, vol. 111, n° 1, 2017, 798.

to the speed of traffic or pedestrians, providing light when users require it and less light when there is no demand.

6 As part of the emergence of studies of night, artificial light, and darkness across multiple disciplines,[11],[12] studies of the history of public lighting technologies and practices have been one of the most prevalent areas of attention. This is undoubtedly connected to the promises that smart-lighting systems contain for the future, but also because public lighting has been taken as a somewhat exemplary case within the study of the history of socio-technical systems and energy use more broadly.[13],[14],[15],[16],[17] Across these (and many other) accounts both lighting and electricity are exemplars of a historically and socioculturally contingent infrastructure, whereby the implementation of technological innovation is shaped by but also produces social contexts. Hughes argues that these technologies need to be understood as systems, the growth of which can be explained exclusively by its contingency, rather than requiring any additional explanatory tools.[18] In an editorial to a recent special issue of this journal on histories of light and darkness, Le Gallic and Pritchard argue that "The history of public lighting offers a classic illustration of infrastructure: extensive, often invisible, technological systems that are taken for granted—at least until they fail".[19] Within that special issue, Dunn's paper on the history of lighting in Manchester provides a good counterpoint to this article, focusing as it does on a broad-brush history of lighting in that city from the early nineteenth century to the LED-era.[20] Dunn's story of Manchester offers many similarities to the history of lighting in Newcastle, but where his article covers an extended period of time, this one dives into moments of transition between the different lighting systems.

7 Despite this wealth of study, the research on historical transitions in public lighting has not been extensively applied to understandings of the contemporary transition. Work in energy studies has contrasted transitions with notions of path-dependency: Nordensvärd and Urban, for example, define path-dependency as "a form of lock-in",[21] while Mori contrasts path-dependent energy systems with transitions driven by niche innovators.[22] I argue that this opposition between path-dependency and transition is misleading; transitions are path-dependent, playing-out in the contextual settings into which they are inserted. This is somewhat akin to what Strambach calls 'path-plasticity', which "describes a broad range of possibilities for the creation of innovation within a dominant path of innovation systems".[23] In other words, it is not necessary to break with path-dependency in order to innovate; rather, the capacity of innovation is dependent upon the elasticity of institutions and the "interpretative flexibility"

11 Christopher Kyba *et al.*, "Night Matters—Why the Interdisciplinary Field of "Night Studies" Is Needed", *J—Multidisciplinary Scientific Journal*, vol. 3, n° 1, 2020. Url: https://www.mdpi.com/2571-8800/3/1/1/htm (accessed 07/12/2020).

12 Michele Acuto, "We Need a Science of the Night", *Nature*, vol. 576, 2019, 339.

13 Schivelbusch, "Disenchanted Night" (cf. note 6).

14 David Nye, *When the Lights Went Out: A History of Blackouts in America* (Cambridge, MA: MIT Press, 2010).

15 Joachim Schlör, *Nights in the Big City: Paris, Berlin, London 1840-1930* (London: Reaktion, 1998).

16 Thomas Parke Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: John Hopkins Press, 1983).

17 Sandy Isenstadt *et al.* (eds.), *Cities of Light: Two Centuries of Urban Illumination* (London: Routledge, 2015).

18 Hughes, *Networks of Power*, 2-5 (cf. note 16).

19 Stéphanie Le Gallic and Sara B.Pritchard, "Light(s) and darkness(es): Looking back, looking forward", *Journal of Energy History/Revue d'Histoire de l'Énergie,* vol. 2, 2019. Url: energyhistory.eu/en/node/137.

20 Nick Dunn. "Dark Futures: the Loss of Night in the Contemporary City?" *Journal of Energy History/Revue d'Histoire de l'Énergie,* vol. 2, 2019. Url: energyhistory.eu/en/node/108 (accessed 07/12/2020).

21 Johan Nordensvärd and Frauke Urban, "The Stuttering Energy Transition in Germany: Wind Energy Policy and Feed-In Tariff Lock-In", *Energy Policy,* vol. 82, n° 1, 2015, 15.

22 Akihisa Mori, "Socio-technical and Political Economy Perspectives in the Chinese Energy Transition", *Energy Research and Social Science*, vol. 35, n° 1, 2018, 28-30.

23 Simone Strambach, "Path Dependency and Path Plasticity: the Coevolution of Institutions and Innovation - the German Customized Business Software Industry", *Working Papers on Innovation and Space,* Philipps-University Marburg, Department of Geography, n° 02.08, 2008, 4. Url: www.econstor.eu/handle/10419/111860, (accessed 07/12/2020).

of actors.[24] Transitions are not externally driven moments of change, but dependent upon the flexibility or plasticity of the pre-existing paths. This aligns with Hägerstrand's time-geography, which emphasizes the intersection "trajectories" of actors which result in "processes which cannot unfold freely as in a shielded laboratory but have to accommodate themselves under the pressures and opportunities which follow from their common coexistence in terrestrial space and time".[25] Moments of transition in lighting show these trajectories or paths as intertwining and interlinked, rather than as ruptures of breaks. Describing early twentieth century American city streets, Baldwin says that there was "a crazy quilt of different forms of illumination: arc light towers, arc light gloves near street level, incandescent lights, gaslights with and without mantles, lamps burning gasoline or kerosene".[26] Despite the eventual dominance of the orangey-yellow electric sodium-gas based lights through the twentieth century, all cities retained and retain something of a patchwork of different lighting technologies.[27] Moments of technological transition highlight diversity in technological provision, as the 'old' technologies find new ways of persisting alongside newer developments.[28] Thus in understanding the promises of LED lighting systems, we need to understand both the paths with which these technologies intertwine, and the new trajectories that emerge out of the transition.

FLEXIBILITY AS POLYFLEXIBILITY

8 It is helpful to distinguish flexibility from dynamism. If flexibility is understood as the capacity for variation within a system, dynamism should be understood as the specific capacity of the system to change. It is thus possible to imagine an energy system which is quite flexible, but not particularly dynamic. For example, in their research into domestic use of energy, Powells et. al., argue that peaks in energy demand can be conceptualized as the result of the configurations of differing social practices.[29] Similarly, Shove et. al. argue that the persistence of car-dependency in society is a result of the obduracy of "infrastructural arrangements and... the spatial and temporal connections between practices that these enable".[30] In both cases, there is a relatively high-level of everyday flexibility experienced by the user, who can drive their car or use their washing machine when they want. Yet the lock-in of practices and infrastructures means that both systems lack dynamism. Conversely, Hirsch argues that very finely tuned systems can reach a state of 'technological stasis', in which "technical, managerial and "social" forces reach a stalemate characterized by unimproved technological performance".[31] While this stasis might seem to be lacking in dynamism, it can in fact lead to very dynamic and unstable systems, as the absence of flexibility in a system means that small changes can lead it to collapse (Hirsh calls this an "unstable equilibrium"). In other words, while dynamism is related to flexibility, this relationship is a complex one.

These arguments also show the need to 9
study infrastructure and practice together. Infrastructures facilitate some practices over others, and in turn people adapt to enact certain social practices while rejecting others. Habits, desires and imaginations form, and flexibility is reduced. Policymakers and energy-system oriented academic research has only lately started to pay attention to this relationship between practice and infrastructure[32],[33]; too often, infrastructural changes are proposed with a

24 *Ibid*.

25 Torsten Hägerstrand, "Geography and the Study of Interaction between Nature and Society", *Geoforum*, vol. 7, n° 5-6, 1976, 332.

26 Peter C. Baldwin, *In the Watches of the Night* (Chicago: University of Chicago Press, 2012), 159.

27 Arup, *Cities Alive,* 39 (cf. note 1).

28 David Edgerton, *The Shock of the Old : Technology and Global History since 1900* (London: Profile, 2008), 11.

29 Gareth Powells *et al.,* "Peak Electricity Demand and the Flexibility of Everyday Life", *Geoforum,* vol. 55., n°1, 2014, 44.

30 Elizabeth Shove *et al.,* "Conceptualising Connections: Energy Demand, Infrastructures and Social Practices", *European Journal of Social Theory,* vol. 18, n°1, 2015, 276.

31 Richard F. Hirsh, *Technology and Transformation in the Electric Utility Industry* (Cambridge: Cambridge University Press, 1989), 191.

32 *Ibid*., 283-285.

33 Powells, "Peak Electricity", 50 (cf. note 29).

presumed direct causal impact on social practices, whereas research shows that to enact change, both infrastructure and the practices themselves require attention.[34] Research driven by theories of social practice has more recently done the job of showing the need to open up the range of actors involved in energy systems,[35] but the relative newness of this area of research, means that there are several actors whose impact has received less attention. Of note, the relationships between technological transition and legal, financial and governance frameworks have received less attention. However, when dealing with energy systems, we often find that change is shaped by the complexities of such frameworks, particularly as many systems incorporate a mixture of public, collective private and individual private actors (with some actors falling into more than one of these categories).

10 In other words, there are many different actors to yet consider when exploring polyflexbilty as opposed to flexibility. The term Polyflexibility draws directly from Lefebvre's 'polyrhythmia', where it appears alongside two companions, 'eurhythmia' and 'arrhythmia'. [36] Lefebvre describes a dialectic, in which eurhythmia are the merged rhythms of normed everydayness, while arrhythmia are the discordant, pathological rhythms of suffering and hurt. The synthesis of these is the polyrhythmia, the rhythms of everyday life. Crucially for Lefebvre, analysis of polyrhythmia "simultaneously discovers the multiplicity of rhythms and the uniqueness of particular rhythms".[37] Polyrhythmia contain both eurhythmia and arrhythmia; as Blue puts it:

> "within a given polyrhythmia there exists bundles or collections of rhythms that are in sync, healthy, and 'normed'. Lefebvre describes these rhythms as eurhythmia. In that same polyrhythmia there are rhythms that are desynchronising, pathological, and different. He describes these as arrhythmia".[38]

In other words, independent and unique rhythms 11
coordinate in complex ways, not simply facilitating each other but also sometimes operating against dominant rhythms. We can see here an analysis which shares many concerns with the approach taken in practice theories, arguing that practices and infrastructures are simultaneously unique and interdependent, although Lefebvre attributes change largely to class intervention, [39] rather than the coevolution of materials and practices. Still, his ethnographic approach and focus on everyday life have led to Lefebvre's work being explored alongside practice theories. Returning to Blue, he argues that Lefebvre helps provide a framework to "describe the emergence and entrenchment of connections between practices",[40] as well as offering an approach which emphasises the variety of contradictions between practices.

In adapting the term polyrhythmia to the term 12
polyflexibility, I seek to highlight how flexibility exists both at the level of an assemblage as a whole, and at the level of the individual practices and actors which constitute that assemblage. This speaks to the previously cited work that conceptualizes transitions as dependent upon and part of a trajectory with existing paths,[41] rather than as externally triggered ruptures. Even rather rigid and fixed systems are thus likely to contain some flexibility; this relational flexibility is neither fully flexible nor fixed. As with Lefebvre's polyrhythmia, polyflexibility is composed of both forms of flexibility, and forms of stasis. As an emergent characteristic, polyflexibility is always relational and contingent. Within practice theories, flexibility is understood as a feature of both practices and actors; or as Powells *et al.* write, "flexibility varies between

34 Elizabeth Shove, "Beyond the ABC: Climate Change Policy and Theories of Social Change", *Environment and Planning A: Economy and Space*, vol. 42, nº 6, 2010, 1274.
35 Powells, "Peak electricity", 44 (cf. note 29).
36 Lefebvre, *Rhythmanalysis*, 16 (cf. note 5).
37 *Ibid.*, 17.
38 Stanley Blue, "Institutional Rhythms: Combining Practice Theory and Rhythmanalysis to Conceptualise Processes of Institutionalization", *Time & Society*, vol. 28, nº 3, 2019, 940.
39 Lefebvre, "Rhythmanalysis", 14 (cf. note 6).
40 Blue, "Institutional Rhythms", 925 (cf. note 38).
41 Strambach,"Path Plasticity", (cf. note 23).

practice entities and also between performances of particular practices".[42] However, such research has tended to retain a binary division between supply-side and demand-side, even where it has argued that these must be understood relationally. As Rinkinen and Shove note, this has also tended to focus on future trajectories of transitions, with much less attention on the historical paths on which these trajectories depend.[43] Working with Polyflexibility helps move beyond analysing through this binary, instead attuning to different 'modalities' which intersect in an energy system and which have differing levels of flexibility. I introduce modalities primarily as analytical, which are unique to a particular assemblage. In public-lighting, for example, we can identify a technological and infrastructural modality composed of the energy sources used, their capacities, and their transmission; a governmental-bureaucratic modality, composed of both the bodies involved in the governance of lighting, and the legislation to which they are bound; an experiential modality, composed of the modes of engagement that the public have with public-lighting; and a financial modality, composed of both the broad socio-economic system within which lighting is provided, and the specific finances of the bodies responsible for lighting in any given location. Different energy systems would have different modalities, but in this paper I show that flexibility – and stasis – at any one moment comes from both the characteristics of these different modalities, and how they intersect.

13 The difference which this conceptualization makes is to argue that Polyflexibility is flexibility as understood as the result of multiple intersecting actors, practices, technologies and institutions which themselves have their own flexibility. In turn, energy transitions are emergent from this Polyflexibility, rather than externally driven ruptures. This goes beyond widening the net for which actors and practices we consider as part of an energy system. Rather, the concept of Polyflexibility indicates, first, that all forms of flexibility consist of forms of flexibility and inflexibility. The result is that we cannot find an ultimately inflexible or unmoving modality within an energy assemblage. Second, there is also no pure flexibility either: there is nothing which if shifted or moved will somehow entirely unchanged. Third, when describing Polyflexibility, we should describe not just the variety of actors or practices which are flexible, but the *variety of ways in which* those actors and practices can be (in)flexible. These ways of being flexible shift over time as the relationship between different actors, practices and modalities change, and as such both the flexibility of a socio-technical system and the source of this flexibility change over time. A historical understanding of how polyflexibility has operated at different transition moments, in the same place, should help in revealing this.

METHODS

As outlined in the introduction, Newcastle-upon-Tyne is an appealing case study, as the location where early innovations in electric lighting and public lighting took place. Most of the archives consulted were housed by TWAM. Within their archives, three sets of documents proved most useful. The first was the archives of the North Eastern Electric Supply Company (NESCO). Minutes of directors' meetings, alongside copies of correspondence with local authorities and miscellaneous promotional documents were all consulted, covering the period of 1888-1908 and 1936-1948, this latter period of archives ending with the nationalization of energy suppliers in the UK. The second were the archives of the Newcastle-upon-Tyne Corporation, and specifically the minutes of the Newcastle Lighting Committee, which were reviewed from 1883-1908 and 1936-1946. The third set of archives were the records of the Newcastle-upon-Tyne City police, with their documents on lighting regulations and applications for exemptions from 1938-1948 being available. In addition to TWAM's collection, I used the British Library newspaper archives for historical reporting. Between them, 14

42 Powells *et al.*, "Peak electricity", 50 (cf. note 29).
43 Jenny Rinkinen and Elizabeth Shove, "Energy Demand", *in* Jenny Rinkinen, Elizabeth Shove and Jacopo Torriti (eds.), *Energy Fables. Challenging Ideas in the Energy Sector* (Abingdon: Earthscan, 2019), 9.

these three sets of archives offered a comprehensive overview of the planning and management of changes at the two historical moments.

15 Documents for the contemporary era were much more difficult to track down, despite having located similar documents for a neighbouring local authority in research on an associated project.[44] In the case of Newcastle, the terms of its Public Finance Initiative (PFI) mean that many of the relevant policy documents are redacted and unavailable. I therefore had to piece together data from different sources. The first were semi-structured interviews carried out in 2013 for an earlier project on street-lighting decision making, one with an official from Newcastle-upon-Tyne and the second with officials from North Tyneside, a neighbouring local authority with which Newcastle shares a Public Finance Initiative contract with SSE Lighting.[45] The second source is the *Newcastle Evening Chronicle*, the city's largest newspaper which has reported on the transition. Beyond this, the available documents were the minutes of the Newcastle and North Tyneside Join Street Lighting Committee, consulted from 2015-2019, and the PFI performance reports submitted to that committee. Nevertheless, some redacted material means that these sources are not as full as they might be.

16 All three data sources – archival material, policy documents and qualitative interviews, are understood in similar ways as partial, reflecting a distilled and curated selection of broader debates.[46],[47] The approach to all the material consulted drew from a broadly constructionist framework, in which the data was considered to be a partial representation of the ways in which different actors have constructed their social world, with the researcher's job being to try and untangle that process of construction.[48] All documents, including the interview transcripts, were coded directly or, in the case of archival material, had coded notes made about them. All documents in the archives were consulted between June-August 2019. The three sections below outline different how flexibility has varied, across the three case study moments.

VARIATIONS IN INSTITUTIONAL FLEXIBILITY

> "If the electric lighting is to be done cheaply, as large a portion of the City as possible should be covered, and not in the isolated manner it is now carried out in Newcastle"[49]

17 Despite its reputation as a city of lighting innovation, Newcastle ended up falling behind many other British cities in its introduction of electric lighting. By 1897, the city's lighting committee was sending a delegation to South Shields, a much smaller town ten miles to the east of Newcastle at the mouth of the River Tyne, to look at the electric lights that had been introduced there.[50] Indeed through the period 1896-1902, the minutes of the lighting committee reveal a repeated series of reports, visits and localized experiments which saw a range of different proposals and costings produced by the city's lighting officer. This stands in contrast to the quick development of the electric network as a whole within the city, which was used as an exemplar in within the UK and operated at a more complex and higher capacity than London.[51] The extract opening this section is from one of the lighting officer's many reports, perhaps indicating a frustration with the lack of decision-making and change on behalf of the committee. The major

44 Ankit Kumar and Robert Shaw, "Transforming Rural Light and Dark under Planetary Urbanisation: Comparing Ordinary Countrysides in India and the UK", *Transactions of the Institute of British Geographers,* vol. 45, n° 1, 2020, 155.

45 Robert Shaw, "Streetlighting in England and Wales: New Technologies and Uncertainty in the Assemblage of Streetlighting Infrastructure", *Environment and Planning A,* vol. 46, n° 9 , 2014, 2228.

46 Annulla Linders, "Documents, Texts and Archives in Constructionist Research" *in* James Holstein and Jaber Gubrium (eds.), *Handbook of Constructionist Research* (London: The Guildford Press, 2008), 469.

47 Robyn Longhurst, "Semi-Structured Interviews and Focus Groups" *in* Nicholas Clifford *et al.* (eds), *Key Methods in Geography* (London: Sage, 3rd ed., 2016), 153.

48 Linders. "Documents, Texts and Archives", 469 (cf. note 46).

49 Minutes of the Newcastle Lighting Committee, 12/01/1893, TWAM.

50 Minutes of the Newcastle Lighting Committee, 09/07/1897, TWAM.

51 Hughes, *Networks of Power,* 228 (cf. note 16).

barriers to change, in this case, seemed to be threefold. The first was financial. An initial installation of arc electric lighting in central streets of Newcastle in 1890 appeared to offer significant savings over existing gas lighting. Enthusiasm at this point was high: the lighting officer's report on the first electric lights stated that:

> "the lamps have given great satisfaction and I have no hesitation in saying that the lighting committee art to be congratulated upon the result of the experiment, and that the problems of satisfactorily lighting our main street with the electric light has been brought considerably nearer by the action of your committee".[52]

18 Progress soon stalled, however. In particular and despite satisfaction with the lighting, the committee seemed to be unable to make the finances of the installation across the city of the necessary infrastructure for lighting work. Several letters between the lighting committee and NESCO seemed to reach a standstill on the issue of the cost of installing the necessary wires. Looking at NESCO's own archives, agreements with suburban authorities such as the 1901 agreement with Fenham Urban District Council, covering an area to the west of Newcastle city center, seem to have been reached more quickly.[53] Here, the added cost of installing new infrastructure alongside rapidly growing suburbs was lower than digging into Newcastle's already-densely developed city center, with overlapping medieval, eighteenth century and nineteenth century urban infrastructure.

19 Second, the introduction of electric lighting was more complicated because of the existing relationship between the local authority and the gas supply company. Almost immediately, the lighting committee showed concern about this relationship, but in the first instance the gas company wrote with their approval of small scale experiments with electric lighting. However as the first set of proposals were developed, the gas company responded more aggressively, by threatening to raise prices.[54] The lighting committee responded by reducing the number of hours' lighting being provided, in order to offset the increased cost of gas.[55] In this instance, the inflexibility of the gas company was offset by increasing flexibility in terms of the hours of lighting provided; this reemphasizes the insights that the transition is path-dependent, with existing technologies shaping the introduction of the new. Third, the introduction of electricity was also held-back by a lack of political power and will. At this time, British local governance was relatively weak.[56] With infrastructure provided entirely by private companies, the Newcastle Lighting Committee only had power as the *buyer* of electricity or gas. As such they were unable to prevent the emergence of a duopoly of electrical provision in Newcastle among two companies, NESCO and the Newcastle and District Electric Lighting Company (NDELC). These companies agreed that rather than compete by price, NESCO would supply the west of the city and NDELC the east.[57] In November 1891 the committee reacted angrily to the refusal of these companies to break this agreement, expressing their belief that they had "a right to request supply from whichever provider the committee desires".[58] By mid-1892, however, the committee relented, powerless in the face of the institutional inflexibility of the two companies.[59] Hughes shows how in Newcastle, the local electricity supply companies – particularly NESCO – prioritized the overall network supply rather than just lighting.[60] While this meant Newcastle became a higher consumer of electricity than other British

52 Minutes of the Newcastle Lighting Committee 16/07/1890, TWAM.

53 Agreement between Fenham and Benwell Urban District Council and North Eastern Electric Supply Company. 09/03/1904, TWAM.

54 Minutes of the Newcastle Lighting Committee 12/03/1890, TWAM.

55 *Ibid.*

56 Hughes, *Networks of Power*, 229 (cf. note 16).

57 NESCO, "Division of Electricity Supply with Newcastle and District Electric Supply Company", 17/03/1890, TWAM.

58 Minutes of the Newcastle Lighting Committee, 17/02/1891, TWAM.

59 Minutes of the Newcastle Lighting Committee, 17/05/1892, TWAM.

60 Hughes, *Networks of Power*, 251 (cf. note 16).

cities,[61] the lighting committee faced a difficult task in engaging businesses that had priorities elsewhere.

20 Commercial agreements have also led to inflexibility in Newcastle in recent times. As noted in the methodology, Newcastle City Council, North Tyneside Council and SSE operate lighting together under a PFI agreement, lasting 25 years from 2004. In interviews in 2013, staff at both councils said to me that at the time, LED lighting was not being installed as costs had already been incurred under that PFI agreement to replace orange 'SOX' street-lighting with white 'SON' street-lighting: "We've gone through an expensive PFI in whichever way you look at it, cheap or expensive which every way you look at it but there's a lot of cost involved so if we are going to fund the next stage 1) the money's got to be sought from somewhere 2) it's got to have a good payback... something like an LED – stop me if I'm wrong here but – are good units but they're quite expensive".[62] Here, the institutional inflexibly was created by the PFI award, which restricted the room for maneuver of Newcastle and North Tyneside councils. As in the late 1890s, Newcastle found itself falling behind neighbours such as Gateshead, which started the process of introducing LED in 2012.[63] By contrast, it was only in 2017 when the widespread introduction of LED lighting was approved by Newcastle City Council; I infer that this reflects the reduced cost of LED lighting by that time, although the discussion of this introduction is redacted in council minutes.[64] The replacement scheme has only just begun at the time of writing, while many other cities have been operating LED lighting for several years.

Institutional flexibility was at its lowest during the wartime Blackout period (1939-1946). The archives at this time reveal numerous letters requesting permission for extra lighting, all of which were subject to police inspections and many of which were rejected. Chief Constable Crawley of the Newcastle City Police, who appears to have personally adjudicated on all requests for exemptions, rejected the majority of requests made to him between 1939 and 1944. Restrictions in Newcastle-upon-Tyne were harsher than in many other cities because of its location near the east coast of England.[65] Sill there, were some exceptions. A request came through in September 1939, shortly after the introduction of lighting restrictions, from the city's head postmaster:

> "I would like to bring to your notice the need for some lighting in the archways leading from Neville Street to Orchard Street and Westgate Road to Calvering Place. We have a considerable number of officers leaving and commencing work round about 10.00pm daily and the absence of light of any kind has already lead to at least one of my staff being injured. Members of the female staff have also complained of molestation".[66]

21 Permission was granted for a small light to be hung under the archways, but this was one of few exemptions granted.

22 Newcastle at all three moments has had lower levels of flexibility than many other British local authorities, though for contrasting reasons. In the 1890s-1900s, local authorities in the UK had relatively little capacity to combat powerful

61 Ibid., suggests ten times higher than in London.

62 Interview with author, 2013.

63 Gateshead Borough Council. "Street Lighting Tender Gateshead: Supply of Luminaires for Phase 3 of the Street Lighting Carbon Reduction Project" 02/07/2012. Url: https://www.government-online.net/street-lighting-tender-gateshead/ (accessed 26/05/2020).

64 Approved Cabinet Minutes, 20/07/2017, Newcastle City Council. Url: https://democracy.newcastle.gov.uk/documents/b25988/Approved%20Public%20Minutes%2020th-Nov-2017%2016.30%20Cabinet.pdf?T=9 (accessed 26/05/2020)

65 The specific case of extra restrictions on public lighting in Newcastle was raised in the House of Commons by David Adams in ministerial questions to the Home Secretary, John Anderson, in August 1940. The Home Secretary strongly defended these extra restrictions in Parliament: "In a place so near the coast as Newcastle defence considerations make it impossible to allow street lighting of any kind". Hansard, *House of Commons, Oral Answers to Questions,* vol. 360, col. 1444. Url: https://hansard.parliament.uk/commons/1940-08-22/debates/e10540a8-2aec-46b4-b344-d6ad09c0421d/CommonsChamber (accessed 26/05/2020).

66 Letter to Chief Constable Crawley, 15/09/39, TWAM.

capital, albeit they had significantly more than 50 years previously,[67] and as such they were weak in the face of the objection to change that came from local energy companies. Newcastle seemed in this matter to have a particularly reticent local council, operating more slowly than both similarly sized cities in northern England and central Scotland, and smaller towns within Tyne and Wear. By contrast in the Blackout period, flexibility was constrained by very strong governmental control; the absolute and moral authority of the state-war machine combined with geography to restrict even very small forms of public lighting. Here, this authority facilitated dynamism where the state required it – both the start and end of blackout restrictions were relatively swift – but was otherwise very inflexible. In contemporary Newcastle, flexibility has once again been constrained by commercial relations, but this time round the capacity to make profit has broken through more quickly than in the 1890s. To understand the relative speed of action in the 2010s compared to the 1890s-1900s, we need to understand polyflexibility: ultimately, it is the intersection of relatively high flexibility in the financial modality with low flexibility in the governmental modality which led to change in Newcastle in the contemporary era, whereas both were equally inflexible in the 1890s-1900s. In other words, institutional flexibility is itself multiple, dependent upon organizational structure, legal power, moral/authoritative power, financial resources, and the capacities of individuals within the institution.

MEASURING AND PRESENTING DATA TO FACILITATE FLEXIBILITY

23 As previously described, Newcastle-upon-Tyne city council agreed a deal for an LED lighting replacement scheme, which began in the spring of 2019. Commercial restrictions have resulted in limited availability of information about the LED replacement programme. Nonetheless, the minutes of the Joint Street Lighting Committee held between Newcastle and North Tyneside do reveal some of the motivations. In the meeting of August 2016, it is noted that reports on the PFI should include "a section on electricity consumption, which was not previously included".[68] The introduction of this data in 2016 – and indeed its absence in previous reports – is revealing of the emergence of the importance of energy consumption in the management of lighting through the 2010s. This reflects in part that LED technologies suddenly created the opportunity to both save money and reduce energy use. This provides an example of the role of data in facilitating forms of flexibility.

North Tyneside council were more confident 24
in the new technologies than Newcastle, and started a programme of dimming, trimming and part night switch off in 2014, followed by a transfer to LED lighting in 2017. As part of the 6 monthly PFI reports to the two local authorities, the differences between the originally projected and actual energy consumption for the previous twelve months is reported, and the evolution of this since North Tyneside began its lighting reduction plan is shown in figure 1.

Year	Newcastle	North Tyneside
2013	98.86	99.25
2014	98.81	89.70
2015	98.10	80.54
2016	97.85	78.65
2017	91.41	75.08
2018	89.51	65.40

Figure 1: Percentage of projected energy consumption actually used per year. Source: Author.[69]

67 Jan Palmowski, "Liberalism and Local Government in Late Nineteenth Century England and Germany", *The Historical Journal,* vol 45, n°2, 2002, 382.

68 Minutes of the Joint-Street Lighting Committee, 10/08/2016, North Tyneside Council. Url: http://ntc-web-democratic-archive-public.s3-website.eu-west-2.amazonaws.com/Files/JSL/JSL-2016-08-10_Joint_Street_Lighting_Committee_10-08-2016_-_Minutes.pdf (accessed 07/12/2020).

69 Table compiled from several editions of the Minutes of Joint-Street Lighting Committee, 2013-2019, Newcastle City Council and North Tyneside Council. Url: http://ntc-web-democratic-archive-public.s3-website.eu-west-2.amazonaws.com/JSL.html, (accessed 07/12/2020). Url: https://democracy.newcastle.gov.uk/ieListMeetings.aspx?CId=500&Year=0, (accessed 07/12/2020).

25 While both local authorities saw efficiencies due to general improvements by the PFI partner SSE, the savings gained by North Tyneside first by dimming in 2014 and moving to LEDs from 2017 are clearly shown in this table, such that North Tyneside was in 2018 saving £508,000 a year more than Newcastle, in comparison to projected energy use.[70] That these figures are also reported on in terms of saved expenditure suggests that a major driver behind these changes was the opportunity to save money. What we see in this reporting is that an energy assemblage which was apparently inflexible when my qualitative interviews took place in 2013, became flexible when, first, reliable data could be produced which showed the value of change; and second, as the cost implications of being inflexible continued to rise. As such, the financial modality and overall flexibility were reliable on availability of data.

26 Data was also important in the move between gas and electric lighting in the 1890s and 1900s. In this period, the main push for flexibility came through reports of Newcastle's lighting inspector, and visits by the committee members to other cities. In addition to the visit mentioned to nearby South Shields previously, in 1896-1897 visits were made to Sunderland, Edinburgh, Bolton and Southport.[71] These visits were used alongside data on the practices of other local authorities, obtained through written requests.[72] Technical reports on different technologies were provided by the (ever-patient) lighting inspector on different technologies and approaches to electric lighting are provided in July 1897, March 1898 and February 1900. It was this final report that contributed to the authorization of a fresh round of trials of electric lighting, which in turn led to the eventual approval of the installation of a greater number of electric lights in 1902.[73] Here, we can see that what was required for flexibility on behalf of the bureaucracy of the lighting committee and the local authority, was for electric lighting to be presented in terms with which bureaucracy could cope. As has been the case in the 2010s, flexibility was only possible once electric lighting had been transformed into the sort of known, reported upon and authorized data that bureaucracy recognizes. As well as being dependent upon the intersection of multiple modalities, polyflexibility is also about the translation of information into data that is recognizable to different modalities within an assemblage.

27 While Newcastle's PFI agreement in the 2010s was initially slow to change compared to other contemporary local authorities,[74] it has proved to be the flexible once a particular path was agreed upon. After agreeing on the transition to LEDs, barriers to flexibility were quickly removed, and resources allocated to the new installation programme. We can contrast the two periods by looking at the speed of change. In the contemporary era, LED lighting was approved in November 2017, with installations currently taking place and a projected point of conclusion in September 2021. By contrast, despite the first trial of permanent electric lighting taking place in Newcastle in 1890,[75] the decision to have a widespread programme of electric lighting installation was not taken until 1902, and only around 800 new electric lights had been installed by 1910.[76] In both cases, what was important in producing flexibility was the presentation of data in a form that could be recognised across the assemblage. Polyflexilbity, as a concept, highlights to us that flexibility is a result not just of interacting flexibilities, but also how this flexibility is communicated. This raises the role of measurement and presentation of data as central to understanding the flexibility of an assemblage.

70 *Ibid.*

71 Minutes of Street Lighting Committee, 1896-1898, TWAM.

72 Minutes of the Street Lighting Committee 14/12/1896, TWAM.

73 Minutes of the Street Lighting Committee 25/02/1902, TWAM.

74 Shaw, "Streetlighting", 2235 (cf. note 45).

75 Minutes of the Street Lighting Committee 16/07/1890, TWAM,.

76 Minutes of the Street Lighting Committee 20/12/1910, TWAM.

TECHNOLOGICAL PROMISES AND LIMITATIONS

28 The Blackout in World War 2 was managed and facilitated by a series of more or less innovative technologies.[77] Its management was the responsibility of local police, but its efficacy was also monitored by the RAF. In the early months of the Blackout, regular reports from RAF planes were sent to the Newcastle police, reporting mainly on the failure of Blackout measures to conceal the city. For example, a report from September 1939 states that "all towns in the Tyne and Tees area have odd lights visible and Newcastle is clearly recognizable as a town area".[78] By October 1939, these reports had become much more positive, and reports of visible breaches of the Blackout almost disappear from the archives.[79] New technologies started to emerge, providing businesses alternatives to forms of lighting that were visible from the sky. In Newcastle, however, very few of these were applied. As noted previously, Newcastle's location and arms industry made it a primary target, and Chief Constable Crawley was unmoved by technological innovation. For example, in November 1939, W.M. Storey of the Imperial Tobacco Company requested permission to install internal illumination of cigarette machines "with one low wattage blue lamp (5 watts)", noting that "permission has been granted by certain local authorities throughout the country".[80] Crawley wrote back, denying the request, on the grounds that lighting from automated machines was not covered in any listed exemptions.[81] By 1943, in a request from central government for a list of exemptions granted, only 11 were listed, almost all concerning the ability of shipyards to use lighting at night when emergency repairs were required, although this list excluded the centrally managed exemptions given to railway companies for repairs.[82] The Blackout period thus saw technological innovation, but this innovation was in the case of Newcastle unable to produce flexibility due to the strong state.

29 Technological innovations also helped bring about the end of the Blackout period. On the 15th November 1943, the Newcastle Lighting Committee were informed that a complete blackout was no longer necessary, and that 'starlighting' – the restricted form of street-lighting that had been provided in cities away from the east coast – could now be used in Newcastle as well.[83] However, this lighting only provided any value in mid-Winter, and six weeks-notice was required to manufacture the fittings that would be applied to street-lights to allow this. Combined with labour shortages, this meant that there was very little opportunity to introduce starlighting into Newcastle before April 1944, at which point summer brightness meant that all streetlighting was discontinued until August for fuel efficiency reasons.[84] Anticipating further relaxations on restrictions during 1944, the city council set-about repairing as many street-lights as possible. On the 9th September 1944, permitted lighting was increased to 'moonlighting', and "steps were immediately taken to have the streets of the City illuminated as quickly as possible".[85] Here, planning in the form of repairs through the summer of 1944 allowed for this measure to be taken up more quickly. Labour shortages were initially a major limitation, although the gradual reduction in the number of soldiers required on the fronts from late 1944 onwards allowed redeployment to increase the speed of infrastructural repair. By November 1944, 500 lanterns a week were being switched back on in Newcastle.[86] In April 1945 the lighting

77 James Robinson, "'Darkened surfaces': Camouflage and the Nocturnal Observation of Britain, 1941–45", *Environment and Planning A*, vol. 45, n° 5, 2013, 1053.

78 Report to Chief Constable Crowley, 04/09/39, TWAM.

79 Various, Newcastle City Police Archives, 1939-1940, TWAM.

80 Letter to Chief Constable Crowley, 29/11/1939, TWAM.

81 Letter from Chief Constable Crowley, 30/11/1939, TWAM.

82 Letter from Assistant Chief Constable, 12/05/43, TWAM.

83 Minutes of the Street Lighting Committee, 15/11/1943, TWAM.

84 Minutes of the Street Lighting Committee, 05/05/1944, TWAM.

85 Minutes of the Street Lighting Committee, 06/10/1944, TWAM.

86 Minutes of the Street Lighting Committee, 03/11/1944, TWAM.

committee heard that "no further intermediate standards of lighting is contemplated, and the next step at the appropriate time will accordingly be the removal of all restrictions and the restoration of unscreened lighting."[87] Factors other than the danger of enemy bombardment were barriers to the ability to return to more available lighting. Specifically, there were continued fuel shortages which meant that lighting was restricted through the summer months, such that lanterns were switched off between May 1945 and the end of August 1945. Similar restrictions were in place during the summer of 1946 and it was only after this time that the return to 'normal' lighting conditions was made.[88]

30 The technological modality was therefore a relatively weak part of the flexibility of Blackout-era public lighting. Both the contemporary installation of LED lighting and the slow move towards gas lighting in the 1890s-1900s show periods at which technological and infrastructural capacities were more important. In both instances, a source of difficulty was the conflict between the technological and the infrastructural. Specifically, the difficulty of installing new infrastructure into an already densely built-upon city was a major factor restricting flexibility in early 1900s Newcastle, and 2010s Newcastle. In the contemporary case, existing columns have proved unsuitable in many cases for the specific lighting capacities of LEDs, with their height and spacing designed for the intensity and diffusion of sodium-based light bulbs. In an interview prior to the decision to transition to LED lighting, an official one of the councils involved in the joint North Tyneside/Newcastle scheme said:

> "One of the issues that we have is that because we've got new lampposts if we were going to do lighting changes to try and reduce the energy we're not going to reposition lampposts, we want to use the existing lampposts and some LEDs can't quite achieve the performance standards based on what we currently have."[89]

In other words, the different technological capacities of LEDs compared to sodium-based lights mean that different infrastructure is required to implement them. 31

While these two transitions show similar infrastructural inflexibilities, in both cases there is little evidence of public opinion creating inflexibility. When the installation of the first permanent electric lighting occurred in 1890, the *Newcastle Courant* proudly asserted that "each lamp has a light of 1500 actual candle power, and is most brilliant and effective",[90] although the same paper had as early as 1881 proclaimed, based on Swan's experiment in Mosely Street, that "the adoption of the electric light for street lighting purposes is only a matter of time".[91] The relatively slow adoption of electric lighting in Newcastle does not appear to have been commented on in the paper at that time. In the contemporary transition, there is little evidence for strong public opinion on the matter, reflecting research that suggests the issue of LED street-lighting transition generally of low concern, and that many people barely notice where changes have happened.[92] In particular, that Newcastle's transition has come after neighbouring boroughs may have dampened interest. The *Newcastle Evening Chronicle* in the 2010s reported on the transitions to LED lighting in nearby County Durham[93] and North Tyneside, [94] whereas recent reporting on Newcastle's scheme is embedded within wider discussion of the 32

87 Minutes of the Street Lighting Committee, 26/04/1945, TWAM.

88 Minutes of the Street Lighting Committee, 06/09/1946, TWAM.

89 Interview with author, 2013.

90 "North of England News", *Newcastle Courant*, Newcastle-upon-Tyne, issue 11233 03/05/1890, The British Newspaper Archive (BNA).

91 "Local Notes", *Newcastle Courant*, Newcastle-upon-Tyne, issue 10792 04/11/1881, BNA

92 Judith Green *et. al.,* Reduced Street Lighting at Night and Health: A Rapid Appraisal of Public Views in England and Wales, *Health and Place,* vol. 34, n° 1, 2015, 178.

93 "Bright sparks light up lives", *Newcastle Evening Chronicle*, Newcastle-upon-Tyne, 15/10/2015, Nexis Archives.

94 Tony Henderson and Sonia Sharma, "'Trim and Dim' Plan to Cut Street Lighting Bills", *Newcastle Evening Chronicle*, Newcastle-upon-Tyne, 13/11/2013, Nexis Archives.

local authority's response to climate change.[95] In these contemporary cases, the major question is about the financial demand of transition, rather than the experiential qualities of lighting.

33 In both the historical and the contemporary cases, new, brighter, cheaper public lighting was promised, but the existing infrastructural forms were sufficiently inflexible to delay the installation of these new technologies. In both cases public opinion has been relatively neutral to or mildly in favour of transition, with questions of financial value at the forefront of local newspaper reporting. This fits with the outcome that in both cases, technological changes were able to cut through and drive transitions when it became clear that the financial savings of the new technologies outweighed the initial cost of infrastructural change.

DISCUSSION

34 These three cases show a polyflexibility in which transitions emerge from the relative flexibilities and fixities of different actors who make up the energy assemblage. The three cases show contrasting systems of governance: a bureaucratic state in the 1890s-1900s; a strong militarized operation through World War Two; and a PFI in the 2010s. Across the three cases, flexibility is not the same as dynamism. Arguably, the blackout period was the most *dynamic*, in terms of having the fastest pace of change and the ability to quickly redeploy resources and people in order to change the lighting regime. However, this system was also the least *flexible*: there were essentially no mechanisms for inserting flexibility in face of a strong state. Polyflexibility is not simply therefore a sum of the flexibility of different parts of an assemblage, but also an effect of the relations between these parts and the how they can communicate.

35 As such, thinking about flexibility in singular ways has the consequence of embedding fixed patterns within our reading of energy systems.[96] As the three moments in Newcastle's public lighting history show, there have been both different levels of polyflexibility, and different sources of (in)flexibility. In both the 1890s-1900s transition from gas to electric lighting and the contemporary transition, infrastructure was a source significant inflexibility, and smaller suburbs or surrounding towns started energy transitions before the city itself. The two cases differ in the power of the financial modality; by contrast to the 1890s-1900s, the increased power of finance in the 2010s meant that once change was decided upon, the system was highly dynamic: there is perhaps now low flexibility but high dynamism. By contrast, the blackout era was dynamic insofar as a strong state was able to quickly enact change, but to a very inflexible regime. While technological changes were attempted to provide more lighting, the state was largely able to use its power to prevent them from being implemented. In the most recent transition, we see something of a hybrid between the two historical cases.

36 The concept of Polyflexibility has helped me open up an analysis of flexibility which does not use the analytical tool of supply and demand as the main framing device. While often useful, these concepts offer less when considering public lighting, where the demand can be understood either as demand from the state for energy or from the public for lighting, and the supply can be understood as supply by the state of infrastructure, or from energy suppliers for the energy itself. Thinking in terms of Polyflexibility encourages a conceptualization of a relational flexibility which changes over both time and space as different practices and infrastructures mutually produce one-another. It helps conceptualized energy transitions as path-dependent, but not as externally produced interruptions; rather they appear as moments on trajectories.

95 Dan Holland, "Climate Change Row: Council Clash Over Spending on Eco Action", *Newcastle Evening Chronicle*, Newcastle-upon-Tyne, 26/12/2019, Nexis Archives

96 Elizabeth Shove, "Beware a Fixed Approach to Flexibility", *New Power*, 16/10/2019. Url: https://www.new-power.info/2019/10/beware-a-fixed-approach-to-flexibility/, (accessed 26/05/2020).

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