Street-Lighting in England and Wales: New Technologies and Uncertainty in the Assemblage of Street-Lighting Infrastructure

Abstract:

To dim or not to dim? That is the choice that street lighting engineers across the world are currently having to make. In the context of austerity politics, increased local scale responsibility for climate change mitigation and the emergence of technological developments, this choice of how to provide street-lighting has become newly politicized. In particular, new opportunities for street-lighting practice, including the use of efficient LED lighting, and 'Computer Management Systems' for controlling smart urban lighting, have emerged.

This research paper draws from the concept of assemblage in order to argue that the practices of developing policy knowledge in this area of technological change need to be connected with understandings of lived experiences of infrastructure. Through interviews conducted with lighting-engineers at local authorities in England, I explore the techniques and practices involved in generating the knowledge required to make choices with regards to new technologies and innovative practices. In particular, I argue that while drawing on experiments and trials allows local authority lighting engineers to measure and understand certain features of an assemblage, it also leaves a significant gap with regards to the more tacit and experiential ways in which people engage with infrastructure on a day-to-day basis. This results in a number of uncertainties which local authority staff are aware of, but which they struggle to overcome. As such, this research comments on the difficulties inherent to understanding assemblages, and the ways in which choices are made at the intersection of energy policy, social governance and technological innovation.

1. Introduction

> The total of functioning street lights per square mile in Detroit generally is less than half that of comparable national municipalities. This failure in the provision of basic municipal service – **the City is literally struggling to keep the lights on** – is compounded by the fact that many of the street lights that are working do not meet the residents' actual needs." (Orr, 2013)

When Detroit applied for bankruptcy in June 2013, the city's emergency manager Kevin Orr chose to highlight the failure of the city to provide street-lighting as an indication of the city's lack of ability to carry out basic political services. The message was clear: 'keeping the lights on' is a core measure of good governance in contemporary society. Through the twentieth century, street-lighting became a background standardized feature of urban life noticed only when disrupted (Nye, 2010). Yet this is beginning to change, and not just in the extreme example of Detroit (Schulte-Römer, 2011). Under pressure from several different contexts – technological developments (Kostic and Djokic, 2009), the demands of climate change mitigation (Bulkeley et al., 2012) and cuts to local authority (LA) budgets during austerity programmes (Peck, 2012) – local authorities in much of Europe and North America are looking towards changes in how they light their districts, both in an urban and a rural setting. Moving away from previously accepted norms of 'constant provision', LAs are instead looking at dimming street-lights, at forms of 'smart' lighting which provide light in a manner which responds to changing needs, and at switching-lights off permanently in some areas. These changes represent a move away from constant provision of lighting, a key feature of the landscapes of twentieth century modernity, as well as being a moment of interaction between energy policy and various components of social policy and everyday life.

This article draws from a case study of LAs in the North-East of England, consisting of semi-structured interviews with street-lighting engineers. The paper's core argument is that by understanding street-lighting through an assemblage-oriented perspective, we can connect together on the one hand the practices of decision making associated with street-lighting, and on the other hand the 'lived' components of it. Here, a 'lived infrastructure' perspective emphasises the ways in which infrastructure is both practiced in everyday life, and constructed as an object of policy. It engages in the ways in which infrastructure is produced, maintained, adapted and shaped by the practices of its users and creators (Graham and McFarlane, Forthcoming; Graham and Thrift, 2007; Simone, 2004). Here, infrastructures are conceptualised as "life-support systems" (McFarlane, 2011:655), produced by multiples different agents, practices and materials. How are these disrupted through technological change, and how do those who are charged with managing these infrastructures generate understanding about them? This perspective has to date seen little engagement with the emergent work on energy policy which has begun to engage with the concept of practice (Bulkeley and Castan-Broto, 2012; Shove, 2010). Both sets of literature, however, seek to explore how (energy) infrastructures emerge from both the gathering and management of the physical materials of the infrastructure itself, and from the practices, maintenance and adaptations that occur when the infrastructure is being used in everyday life.

This paper seeks to unpack the complexities of dealing with technological change in a complex lived infrastructure, namely street-lighting. By speaking to policy practioners and exploring how they choose which new technologies and practices to take-up, I seek to establish the ways in which

practioners come to know a complex assemblage and the lived components of infrastructure. How do they grasp and understand street-lighting and the new capacities that are represented by technological change? How do they then incorporate the demands of climate change and austerity policies into these? I argue that experimentation is a key technique: this seeks to reduce the complex and hybrid assemblages to a series of smaller and knowable networks. In doing so, however, certain areas of practice and the assemblage are inevitably overlooked – ways of living with infrastructure are not taken into account. To begin this paper, I want to look at the energy policy context within which street-lighting has emerged as a newly political assemblage, before exploring the use of the lived infrastructures perspective.

2. Lived Infrastructures and Energy Policy

Energy use and its reduction has become central to climate change mitigation, which has seen a major shift away from macro- and nation-scale organisation, towards meso- and urban-scale planning. As such, there has been a shift in responsibility for action away from states and intergovernmental organisations, towards urban and municipal governments (Bulkeley et al., 2012). Through a mixture of both legislative and political demands (Peters et al., 2010), local governments have moved and been pushed towards considering how to transition to low-carbon forms of energy use. A key part of this has forced LAs to consider how they use and manage the infrastructure that comes into their remit, forming part of a wider trend in which responsibility and capacity for responding to climate change has been identified at multiple different scales (Mitchell, 2009:53). In a British context, this process continues to develop. Since 2010, LAs have had responsibilities under the Carbon Reduction Commitment Energy Efficiency Scheme, a mandatory carbon trading scheme for all public and private sector organisations with emissions of over 6,000 MWh per year of electricity – covering all LAs in England and Wales (a similar scheme operates in Scotland). This reflects that transitions to low carbon use have been dominated to-date by targets, under a model in which the cumulative reduction in carbon output from multiple private and public sector organisations is expected to result in overall decrease in carbon use (Comodi et al., 2012).

Due to this change in approach, the role of the everyday practices of living has become more important from a climate change perspective. As such, studies of energy policy have called for new "model[s]… in which institutions, infrastructures, and daily life interact" (Shove, 2010:1278). Shove and others have argued that a key part of these would be a shift towards a reconceptualization of behaviour in relation to climate change. Rather than drawing on a psychological 'ABC' (Attitude, Behaviour, Choice) model, this seeks to explain behaviour as emergent from social interaction, and specifically practices (Fuller and Bulkeley, 2013; Shove, 2010; Strengers, 2012). While such a shift is new to energy policy studies, it reflects much longer running interests in social science more broadly, with practice-oriented theories seeking *social* explanations and descriptions of behaviour over *psychological* ones. It is not surprising, then, that key areas of social science which emphasise features such as corporeality, affectivity or relationality are not yet or are only slowly being brought to bear on this area of research.

One area of emergent research which might prove a useful companion to the introduction of practice-based theories into energy policy studies is that of research into lived experiences of infrastructure. Labelled a 'lived infrastructure' perspective, this area of research emerges out work which holds (paraphrasing Gregory Bateson) that infrastructure is fundamentally and always a

relation and never a thing (Leigh-Star and Ruhleder, 1996:112). This relational approach to infrastructure intersects with a variety of trends in social science studies of technology and society, and focuses on the 'incremental' (Silver, Forthcoming) ways in which infrastructure is created out of multiple practices Crucially, this research area conceives of infrastructure as produced through the daily management, use and decision making surrounding infrastructure – in other words, the ways in which infrastructure is practiced by multiple different actants. This emphasises the ways in infrastructure constructs daily urban life (Graham and Thrift, 2007; Parker, 2009), but is also constructed by the day-to-day practices of its users (Simone, 2004). Despite a well-acknowledged conceptual exploration of this, few attempts "have been made to examine the nature, politics and experience of contemporary… lives as everyday infrastructural experience" (Graham and McFarlane, Forthcoming). In particular, then, there has been little to no use of this literature in an energy context, although Silver's forthcoming article is indicative that this may be changing (Silver, Forthcoming).

In discussion of the lived experiences of infrastructure, agency is conceived of as shifting beyond 'practices' and towards the assemblage or '*agencement*' (see Phillips, 2006 for a discussion of the translation of agencement as assemblage). While the concept of assemblage is a complex one, there is limited space to explore it here (Anderson et al., 2012; McFarlane and Anderson, 2011). Bennett's definition works well, however, to capture some of the key features of assemblage: it is "an ad hoc… living, throbbing grouping…; a web with an uneven topography… [and] not governed by a central power… An assemblage, finally, is made up of many types of actants: humans and nonhumans; animals, vegetables, and minerals; nature, culture, and technology" (Bennett, 2005:445n2). In other words, assemblages are much more vibrant, diverse and dynamic than related concepts such as network: they spread and complicate our understanding of agency, relation and power. Vannini and Taggart's exploration of the lives of 'off-grid' residents in Canada, for example, draws from assemblage to explore the diverse range of actants – natural forces, objects, the residents themselves – involved in off-grid living, and the relations between them (Vannini and Taggart, Forthcoming). Indeed, this case is illustrative in thinking about assemblage, practice and infrastructure as it explores the necessary work required to remake infrastructure when 'the grid' does not exist. As a study in the formation of a small-scale infrastructure, this approach might also be applied to the management and maintenance (Graham and Thrift, 2007) of the larger infrastructure. By drawing from assemblage as a concept for understanding street-lighting infrastructure, I seek to go beyond the re-orientation of studies of energy policy around everyday practices, and instead to understand how infrastructures are constituted by a variety of practices, materials, relations and agents.

In the context of the use of assemblage to study everyday infrastructure, it is useful to mention research which has explored 'soico-technical' governance of climate change adaptation or mitigation. Some have argued that this way of experimenting has now become paradigmatic in LA response to climate change (Bulkeley and Castan-Broto, 2012; Corfee-Merlot et al., 2009; North, 2009). Urban infrastructure is the area which has seen the most experiments (Bulkeley and Castan-Broto, 2012), with LAs often having higher levels of autonomy in this area. Experimentation might seem to be a particularly effective way of engaging with assemblages, as it allows people to test

relationships and unintended effects in a variety of ways. Furthermore, in the context of increasingly 'mobile policy', experiments are a useful way of taking on a leadership role in assemblages of policy making (McCann and Ward, 2011).

3. Street-Lighting, Practising Good Governance and Austerity

Crucially, then, an assemblage approach calls for more than just a re-orientation around the practices of energy users. Rather, it requires that we consider in more depth the practices and materials involved at multiple different stages of the production of infrastructure. Here, it is important to connect practices of infrastructure use and practices of policy decision making. Under existing models of climate governance, it is the end 'carbon output' of an organisation which is important, rather than the manner through which carbon savings are obtained. For LAs, there is thus choice in where and how carbon savings are achieved. Street-lighting has proved attractive as it is one of the larger users of electricity and also one of the areas in which the greatest level of autonomy and flexibility remain. Estimates of the overall contribution of street-lighting to energy use and electricity bills vary considerably, but in all cases the figures given suggest a significant proportion. Globally, street lighting is thought to use about 2.3% of all electricity (Kostic and Djokic, 2009), and for at least one LA (The Highland Council) it accounts for 93% of electricity used, although as this for a large rural area, it is likely to be at the upper end of electricity use (Matheson, 2008).

Street-lighting presents an opportunity as it is in a moment of technological innovation. While high pressure sodium (SON) lighting was the dominant technology for much of the twentieth century, the pace of technological developments in street-lighting has increased significantly. White LED lighting was invented in 1997, and LED lighting capable of providing street-lighting was developed by around 2008 (Taguchi, 2008). LEDs, which are digital technology, offer longer lifespans than SON lights. As they project their lights in one direction only, they use much less energy, and can be switched on and off much more quickly.. This reduces light pollution, and makes them compatible with 'smart' lighting systems, known as Computer Managed Systems (CMS). With these, a street-lighting engineer can choose exactly when to switch each individual street light on or off and/or by how much to reduce the lamp power. Fully realised, this can create an intensively managed lighting system in which significantly less energy is used (Papagiannis et al., 2008).

Such developments reflect similar moves in other areas of urban governance, where 'smart' technologies, operating out of control rooms are seen as offering a more efficient, streamlined and targeted way of operating public services. As Kitchin suggests, this generates new questions about how the city is translated into 'code' (Ktichin, 2011), with forms of 'automated governance' shifting power away from decision makers and dispersing it across computer programmes and their operators (Kitchin and Dodge, 2012). However, studies of street-lighting have in the past explored how such changes have occurred through technological developments. As Ekrich argues, "despite night's dangers, no other realm of preindustrial existence promised so much autonomy to so many people" (Ekrich, 2006:152). Studies of the subsequent introduction of artificial lighting into society such as those by Schivelbusch and Schlör, have explored how this extended social control into the night (Schivelbusch, 1988; Schlör, 1998). Similarly, in exploring the history of blackouts Nye argues that creation of the electricity grid created a requirement to connect to national systems. Thus when a blackout occurs, "the social construction of reality breaks down" (Nye, 2010:33). These studies have all explored how society became dependent upon public electricity and lighting during the

nineteenth and twentieth centuries. As Schulte-Römer argues, the latest technological developments in lighting may be representing a new phase in this process (Schulte-Römer, 2011). Again, approaching this problem with the concept of assemblage in mind might help address how such developments reshape power relations, and redistribute control over energy policy across an assemblage.

In the context of this normalization of street-lighting, it has become understood as a key element of 'good-governance' from LAs (Mattingly, 1994: 203). Jakle's history of public lighting in American cities traces how lighting moved from an occasional, dim-to-modern eyes, exceptional feature, towards becoming an object of everyday urban governance and management (Jakle, 2001). As he notes, however, the "tyranny of cost" (p257) has come to dominate the capacities of LAs to provide this lighting, particularly since the 1970s energy crisis. The current financial component of LA funding, the politics of austerity, seems to be an extension of this. For Peck, who raises the cut-backs in street-lighting as an example of austerity urbanism, these financial restrictions indicate that austerity is "a politically imposed condition" (Peck, 2012: 637), under which previously automatic assumptions about governance challenged due to financial necessity. In a few cases, where lighting has been withdrawn all-together, street-lighting may be seen to have reached this most extreme form of austerity politics, labelled by as an 'abandonment' approach to austerity by Tonkiss (Tonkiss, 2013). In most instances this extreme has not yet been reached, but it does raise further the need to take an assemblage oriented approach towards understanding the relationship between decision making practices and practices of everyday use of infrastructure.

4. Methodology

The research project consisted of semi-structured interviews with street-lighting engineers at LAs in North-East England. The project was designed as a small scoping research exercise, so the choice of region was led by pragmatics. The North-East is accessible to the researcher, but provides a good range of LAs, consisting of a mixture of rural, urban and sub-urban LAs. Each LA in the region is also either a unitary authority or a metropolitan borough with de facto unitary authority status. As such, all LAs in the region are the sole highways authority in their area, outside of the trunk road network which is managed nationally. This gives all North-East LAs relative autonomy in their street-lighting choices. The North-East LAs also offer a variety of case studies of current street-lighting management, with five of the twelve LAs currently having PFI deals (see figure 1 for summary of the LAs involved).

Figure 1: Local Authorities in North-East England

Name	Type	Character	PFI?	Participant?
County Durham	Unitary Authority	Rural	No	Yes
Darlington	Unitary Authority	Urban Town	No	Yes
Gateshead	Metropolitan Borough	Urban City	No	No
Hartlepool	Unitary Authority	Urban Town	No	No
Middlesbrough	Unitary Authority	Urban City	No	No
Newcastle-Upon-Tyne	Metropolitan Borough	Urban City	Yes	Yes
North Tyneside	Metropolitan Borough	Sub-Urban	Yes	Yes
Northumberland	Unitary Authority	Rural	No	Yes

Redcar and Cleveland	Unitary Authority	Sub-Urban	Yes	No
South Tyneside	Metropolitan Borough	Sub-Urban	Yes	Yes
Stockton-On-Tees	Unitary Authority	Sub-Urban	No	No
Sunderland	Metropolitan Borough	Urban City	Yes	No

Of the twelve LAs in the region, six participated in in-depth semi structured interviews, which explored their current policy. In one of these interviews, a representative from a PFI firm also contributed to the interview. In addition, a local lighting design company were also interviewed as part of the research, while a LA in a neighbouring region also acted in a consulting role.

Following the interviews, a report for participants and consulting participants was created,[1] which was circulated round to all who had been invited to take part in the research. This report formed the basis of a participatory workshop, in which interview participants, stakeholders and academics contributed. Participatory workshops allow for a more open format of discussion, as well as the opportunity to ask questions which go beyond the confines of the research questions. In the workshop, the main discussions surrounded current lighting priorities, and potential future needs and planning. This allowed for a broader contextual discussion, generating richer data. While participating LAs have been identified, all comments have been anonymized.

Several core themes came out of the research; this paper explores four of them. First, I explore how changing technologies result in the need to develop new knowledge about the street-lighting infrastructure assemblage. Engineers at local authorities rely on trials and experiments for this, and I profile a typology of these. Second, I describe the newly emergent practices of street-lighting which come from this technological innovation. Third, I look at the central driving mechanisms behind a desire to change; and finally, I consider the relationship between street-lighting infrastructure, and other related assemblages and practices.

5. Knowing the Assemblage: Uncertainty and Trials

> "There's an awful lot of companies out there making claims as to what their equipment can and can't do" (Participant 2)
>
> "there's a new LED lantern every week" (Participant 4)

The proliferation of new lighting technologies over the last decade has led to higher levels of uncertainty about the capabilities and qualities of new products and companies appearing on the market. As such, new forms of knowledge about the assemblage of street-lighting infrastructure are required. In the absence of this knowledge, change has been slow - all LAs interviewed were still installing some older technology, specifically SON or Phillips CosmoPolis lanterns, though all were also looking to move away from these. Three of the LAs were looking towards using LEDs as a standard product, with policy changes either proposed or being developed. All but one of the LAs interviewed also required that new residential developments to use LED lighting.

LA participants identified four significant benefits to LEDs. The first, and most important, was the lower levels of energy required to create the same levels of illumination as existing technologies.

[1] The final version of this report can be viewed at (***website redacted for anonymous review***)

Second, participants commented on the advantages of the extended life of LEDs, but noted that this increases the pressure in ensuring that technological choices are correct. Third, with regards to energy use, was the lower electricity required to switch LEDs on and off. This makes LEDs the best type of lighting to use alongside CMS (Gaston et al., 2012). Fourth, the lighting colour of LEDs can be varied. While early LED lights often emitted a 'cold white' light, warmer whites are now available. Potentially, the wider variety of lighting types available can offer choices to lighting engineers: engineers spoke of the possibility of using colder lights in areas that they did not want people to congregate. This indicates an awareness of the possibility for changes in technology to cascade across an assemblage, with street-lighting being used to shape other areas of practice.

While these benefits were identified, however, there remained limited uptake of LEDs. One of the main ways of responding to the uncertainty surrounding future technologies is to try and construct new knowledge, in this instance through trials or tests of lighting technologies and practices.

> "We've got several trials going on at the moment. I think there are 13 different LED types in x, there are another couple of types in x village, so that's been going on about 18 months" (Participant 7)

In tackling climate change, small scale experiments by LAs are often seen as one of the most effective ways of testing new technologies (Corfee-Merlot et al., 2009). At their most basic level, trials help verify manufacturer claims, and illustrate to LA officials and/or the public what new lighting styles will look like. Previous research has generated a typology of urban climate change experiments based upon the area in which they intervene, where urban infrastructure and the built environment account for over 50% of experiments (Bulkeley and Castan-Broto, 2012). However, from an assemblage perspective, we might remark on the limitations of an experimental approach. While creating experiments is a way of reducing the complexity of an assemblage, and therefore dealing with the impossibility of knowing an assemblage (Bennett, 2004), experiments and trials are also limited in what they are able to view. Here, then, by cutting out part of the assemblage, experiments repeatedly overlook certain elements, which in this case are predominantly the lived experiences of infrastructure.

Three trial types were identified in the research. First 'public consultation' is the most common form of trial. Here, one or more technologies are installed in a test street or area. This allows for a comparison of manufacturer claims, as well as helping judgements based around aesthetics, and the practicality of installing different luminaires. Such features are more easily knowable through experimentation and through the forms of measurement which LAs use. Questionnaires gather feedback from the users of the spaces being tested by the trial, while lighting levels are measured in-situ. This means that only certain elements of the assemblage are accessible to lighting engineers, namely, those which are easily measured or which are readily recalled and expressed by participants. However, approaches to understanding lived infrastructure have emphasised that much of our knowledge and experience of engaging with infrastructure is tacit or affective, and non-reflexive (Shove, 2010; Edensor, 2013a). A further limitation to these trials is that their experimental component is taken over by their use to demonstrate the innovative and forward thinking role being taken on by LAs with regards to energy use (Bulkeley and Castan-Broto, 2012). For example, one LA fitted multiple bordering streets with different types of lighting technology, and then walked residents and others stakeholders around the area. Here, it is questionable whether such an

approach could ever get at the lived experience of infrastructure. Rather, their use as ways of showcasing an LA's innovation with regards to energy appears as more important.

Second, 'stealth trials' (a name taken from a participant) can offer a different way of carrying out and operating a trial. These aim to overcome the perceived public aversion to change. These involve implementing new technologies in an area without informing residents in advance. Again, lighting levels can be tested, but a time gap is left before gathering feedback: "if you just do it and wait for the reaction you might get a more genuine feedback" (Participant 3). For these forms of trial, the evaluation tends to be judged by whether people notice the change or not. While more alert to the limitations of 'interrogative methods', that is, interviews and questionnaires, as methods for generating knowledge, stealth trials still do not account for the practised forms of tacit knowledge and action. Latour refers to this as the 'excorporation' (as opposed to 'incorporation') of knowledge: the taking of embodied experience out of the body (ex-corporeal), and translation of it into questionnaires and consultation documents (Latour, 1990). Furthermore, as these trials rely on people coming forward, they presume a certain form of political agency which may be or less present in different communities. Through an analysis of these trials and experiments we can understand that while a valuable tool, assemblages can never be full-known (Bennett, 2005), and as such some uncertainty remains. Equally, this is not to be overly critical of the use of trials and experiments. Rather, it is to raise an analytical point about the limitations of such approaches, based upon their ability to generate knowledge about certain measurable features whilst hiding more embodied, tacit knowledge about everyday life.

Certainly, LA staff are aware of the uncertainties which remain despite their attempts at trials and experiments. Perhaps a result of this, the immediate uptake of LEDs has been limited. Cost is a major issue: while the price has fallen, almost all lighting engineers perceive LEDs as being more expensive than SON and CosmoPolis luminaires. This is in part due to concerns that at the cheaper end of the market, there are multiple new manufacturers offering untested LEDs. These may not offer guarantees for the lifetime of the LED, and amongst participants, rumour abounds about errors made in selecting technologies elsewhere. Other limitations include the issue of recent replacements: many LAs have replaced columns and luminaires within the last decade, the cost of which was calculated over the lifetime of the currently installed luminaires. Any replacement with LEDs may have its financial and environmental advantages undermined if it involves replacing recently installed infrastructure. Some LAs with long-term PFI deals would also have to negotiate contract alterations over LEDs. Despite these obstacles, all participants were aware of the benefits of LEDs, and it is likely that there will be a transition to their use over time. However, under current market and political conditions, a variety of institutional, financial and infrastructural restraints mean that their integration is likely to be gradual (over a period of 20-30 years), rather than rapid.

Technological innovation leads inevitably to periods of uncertainty, with change destabilising relations between agents that might have previously been well established. Latour describes how new technologies encourage the redistribution of "competences and performances either to humans or non-humans in order to assemble into a more durable whole" (Latour, 1993:379). Trials and experiments, when understood as an engagement with a reduced and limited assemblage, will miss some of the elements which are redistributed, and some of the components of the new whole. In particular, the use of trials as publicity tools may undermine their use as consultation events (Bulkeley and Castan-Broto, 2012). Indeed, some lighting-engineers rejected the trial all-together,

instead looking to learn from others: "People are saying to us 'Do you want some of ours [lights]?' 'No' I'm thinking 'What's the point? I can just go [elsewhere] and have a look at 12 streets there" (Participant 4). From a practical basis, this might also open the possibility for trials to occur on a regional basis. This might also allow for the pooling of resources, which could be used to support the generation of more in-depth data with local residents, providing an opportunity to observe and reflect upon day-to-day lived engagements with infrastructure.

6. Innovating Practices

> "We've had fixed dimming in for 15 years so… it was tried and nobody noticed a difference… [at a location where it]dims at midnight and nobody's ever commented on it." (Participant 7)

"Propagation and diffusion are fully a part of the line of innovation" (Deleuze and Guattari, 1987:405). In other words, technological changes take place through practices and relations, as innovations spread through assemblages, as much as in the technological development of new products (Graham, 2004). Indeed, it is new lighting practices - 'dimming' and 'switching off' street lights – that have created public controversy in street-lighting, rather than new technologies themselves. Dimming of street-light levels involves setting luminaires so that they are brighter during the busier periods of the early evening, before dimming at some point as traffic and pedestrian levels fall. This practice "enables considerable energy savings and most often represents a financially justified investment" (Kostic and Djokic, 2009). However, such a practice does not simply appear out of nowhere: it fits into existing practices and those which are taken up will be the practices which best fit the needs created by forces within the assemblage. In the context of 'austerity urbanism' and the demands of climate-change mitigation, then, those practices which save both money and energy will appear most attractive.

Three sets of new practice can be identified. The first, 'pre-programmed dimming', was the most common form of dimming in place at the time of research. Here, lanterns along certain routes are pre-programmed to dim during certain time periods. In some locations, this dimming facility has been used to provide extra lighting: one LA is using this in crime hotspots, so that early evening lighting levels are higher than in surrounding residential areas, before dimming to a standard level. Pre-programmed dimming is the easiest form of dimming to manage – there are no extra costs once installed – but it clearly has limited flexibility.

Second, CMS controlled dimming reflects part of a wider move towards forms of 'automated management' of the city (Kitchin and Dodge, 2012). CMS allow for dimming to be controlled down to individual luminaires, with lighting levels set according to changing traffic flows, special events, changes over the course of the week, local needs or weather forecasts. Control can be passed over to emergency services, allowing for back-routes to be lit more brightly in the event of road closures or other occurrences, and sensors can brighten lights if high levels of pedestrian or road traffic are identified. CMS dimming shows a clear movement of power around the street-lighting assemblage: power is distributed to a more diverse range of agents, as well as to computer programmes themselves (Bennett, 2005). This movement of power creates opportunities. Lighting can be set at the lowest safe level, with brighter lighting only used as and when it is needed – resulting in energy and cost savings. Some of the LA participants interviewed saw CMS as the clear future direction for street-lighting management:

> [Under CMS]we could say well at 8 o'clock or 9 o'clock in the evening the traffic flow reduces so we can dim to a level… then after 10 or after midnight it drops down again so you can look to dim again… The other thing is, is that what it does allow that as an example if you think that, you know, like football stadiums… if you've got a mid-week game on or a match night and they are coming out at quarter to 10, 10 o'clock in the evening you wouldn't want it dimmed down, you… can literally programme these things in to do things of that nature so I think that's an area that can show development" (Participant 2)."

As noted previously, however, such changes create uncertainty, and a level of scepticism seems required: CMS may be viewed as a panacea, able to simultaneously save money, reduce energy use, and provide more effective public services. In practice, CMS will have high upstart costs if implemented, requiring the installation of significant infrastructure and the training of operators. Furthermore, this movement of power across the assemblage will also come with unintended consequences, and public debate has not yet explored the appropriateness of lighting engineers being able to take decisions which shape pedestrian behaviour, for example. While intentions are clearly honourable here, it may be appropriate for there to be a more public debate about the validity of this form of social control (Rose-Redwood, 2011).

The third new practice, switching off street-lights at night, has proved to be one of the more controversial contemporary political issues regarding street-lighting, but has not yet been significantly taken on in the North-East: "The idea of turning them off at midnight was not very well received. Dimming was maybe a little bit more amenable to people" (Participant 2). In residential areas, it is seen as potentially dangerous, with possibilities for litigation and political unpopularity. Nevertheless, two LAs interviewed have started switching off some lights at night: these have been in locations with alternative, and often safer, pedestrianized routes. Participants identified that, with rising energy costs, the need for lighting in certain locations should be rethought. In particular, three locations are viewed as being ideal for switching off: rural traffic routes; business parks; pedestrian routes with alternative paths. As such, switching lights off may be part of a reassessment of the purpose of lights all together. While in the short term, LA participants are not planning to switch off lights, all workshop participants agreed that they were likely to consider switching off in the near future, and expected most LAs to be switching off some lights, either permanently or during the darker periods of night, in the near future.

This is indicative that participants identified certain trends which are not currently prevalent, but will likely increase in importance due to the major forces that are driving change. What is interesting here was a dissonance between the forces which were declared to be most important on direct questioning, and those which emerged as important under further discussion. In particular, while energy use and climate change mitigation was identified as most important when asked about the drivers of change - "energy is behind sort of every sort of decision we make" (Participant 5) – upon further questioning – financial savings appeared to have greater importance. As one participant said, "it's basically a payback, how much energy reduction compared to the cost of the units? They [LEDs] are still quite expensive at the moment" (Participant 2). For example, one of the identified limits to CMS is that while the close control over street-lighting might use less energy, and thus might reduce the LA's carbon footprint, any financial savings would have to be off-set against high up-front purchase costs of both software and hardware, as well as the need to train staff and emergency

services in operating the system. As such, while most participants agreed that austerity was mainly a continuation of tight budgets, many were concerned that its coinciding with this particular moment of technological change limited their ability to ask for the large investments that would be required for CMS. Here, austerity did seem to be working as a politically imposed limit (Peck, 2012; Tomkins, 2013). Questions of measurement were again a problem. Street lighting energy use is currently unmetered, based instead on assumed consumption. Without meters energy savings could not be quantified and as such would not 'count' financially, again reflecting the difficulty in accessing certain components within an assemblage. Participants recognised the political and reputational value of appearing to be leading the drive towards energy saving, but in practice it seems that the underlying financial pressures are the dominant feature.

7. Street-Lighting beyond the Infrastructure

As identified previously, street lighting intersects with a variety of other policy areas. Research into the everyday nature of infrastructures has emphasised the need to develop an understanding of how infrastructure is incrementally assembled from a wider variety of actors and practices (Silver, Forthcoming). The research reported here has found a significant gap in many areas between understandings of how infrastructure is lived, and the knowledge of policy makers.

Two areas where knowledge was strong were in relation to the need to reduce the number and severity of night-time road traffic accidents, and in relation to light pollution. LAs seemed keenly aware of the importance of maintaining road traffic safety. From a road safety perspective, dimming is possible because of improvements in car headlights and road design. As one participant stated, "we would run matrices with the traffic people and we would also look at the lights whether they would need to take them out or install them dimmer. We would look at the whole road layout, how do you do the lighting and it would be passed across to the various traffic engineers" (Participant 7). Similarly, the new lighting practices and technologies discussed were all seen as reducing light pollution, and indeed one participating LA now includes Europe's largest Dark Sky Park (Kielder in Northumberland). This has involved a long period of detailed local planning in order to eliminate light pollution.[2] In both instances, LAs were carrying out the detailed local intervention that Pease argues is most effective in ensuring the efficiency of street-lighting (Pease, 1999). By contrast, questions of fear of crime – which Pease explores – received less detailed attention. In response to a question about this, one participant simply stated "we just follow the British Standards like BS 5489". This was common, with a belief that the necessary reductions or controls over fear of crime would occur if the standards were met. By contrast to the detailed understanding and plans that were made in relation to the road safety and light pollution, plans to mitigate the fear of crime were much more reliant upon meeting lighting standards. This seems to directly relate to the forms of knowledge which were being created out of experiments and trials. Those which are easy to measure, particularly in relation to the technical knowledge of lighting that is necessary in understanding issues of road safety and light pollution, are well understood. By contrast, the embodied and social knowledge required to successfully contribute to reductions of fear of crime, that is the lived experience of infrastructure, were less easily accessed. In this instance, lighting standards were used as a measurable fall-back by participants.

[2] See Edensor, 2013b on Dark Sky Parks

LAs were aware of the possible benefits that street-lighting could bring to two other areas. Lighting and the night-time economy have long been closely connected; indeed one of the first effects of the introduction of public illumination was to create new night-time economies is the nineteenth century (Schlör, 1998). Contemporary attempts to encourage growth in the night-time economy have also used lighting as a tool (see the discussion of Leeds in Roberts, 2006:336). Participants in my research were divided over whether the night-time economy was still an important part of their policy. One stated that: "… I think that [the night-time economy] was something that happened when the economy was booming... that's definitely gone way… from way down the agenda now" (Participant 3), while for others it still retained more importance. Again, though, there was perhaps an absence of a detailed understanding of the role that the experience of the affectivity of lighting *design* might take in shaping and producing the urban night (see Edensor, 2013a; Ebbensgaard, 2014). A similar situation existed for the maintainance of urban mobility and well-being, whereby participants were clear that "we don't want to reduce it [lighting] to where people are too scared to go out and people feel trapped in their homes" (Participant 4). Here, the main response was to be more cautious when making changes in residential areas, with an awareness that significant alterations to existing lighting practices could adversely affect people's lives.

This indicates varying degrees of awareness of the importance and influence of different practices within the assemblage of street-lighting infrastructure. While issues of fear of crime and mobility were both considered important, knowledge of these was low. Road traffic accident levels and light pollution were considered important with more knowledge available, while opinions on the night-time economy were mixed. An assemblage approach pushes us to understand both the easily accessible technologies – the lanterns, the poles and the wires which are the vocabulary of lighting-engineers – which constitute street-lighting, but also by the practices of driving (Thrift, 2004), walking (Edensor, 2010), and the assemblages of the night-time economy (Hadfield, 2006), and fear of crime (Pain et al., 2006), all of which form the lived experience of infrastructure. However, from the position of lighting-engineers, many of these features appear distant: they fall outside their area of competency and knowledge. This does not make their effects on street-lighting or the effects that street-lighting has on these areas, any less real, however. Here, I would not want to be overly critical of LA staff, who as noted previously are working with limited budgets. While all participants were following their legal duties, areas of knowledge outside of the technical developments of lighting technology were either much weaker, or presumed to be covered as long as the British Lighting Standards were being met. Rather, this suggests that the lived experience of infrastructure is a previously unknown or difficult to access part of the assemblage which, I want to suggest in the conclusion, social science may be in a position to help promote.

8. Conclusion

Research into energy infrastructure has only lightly engaged with the concepts of everyday practice and assemblage to date (Graham and Marvin, 2001; Graham and McFarlane, Forthcoming; Harrison and Popke, 2011). This paper has revealed that this lack of research is matched by significant gaps in practical knowledge of policy makers too. This is indicative of a need to go beyond a 'turn to practice' (Fuller and Bulkeley, 2013; Shove, 2010) and to push further towards assemblage-theory informed approaches to understanding the social. In this research, I've argued that the practices of policy makers are only able to access certain parts of the assemblage. In particular, the experimental approach, while effective at targeting the technical details of lighting standards and certain forms of

public knowledge, is poor at accessing the relationship between street-lighting and everyday life. While the various social roles of lighting are broadly recognized by lighting engineers, their ability to understand these is therefore limited. From an assemblage perspective, it would be incorrect to identify either austerity politics or climate change mitigation as sole causes of this inability to connect to certain areas of knowledge, yet they do also strongly contribute by generating pressures which limit the ability to innovate in knowledge development. While lighting standards are clearly necessary and important, these can also act as 'fall-back' measures, allowing gaps in knowledge to be covered.

What energy and austerity policies have done is to mix technological developments, producing a moment of choice for lighting engineers, which will shape energy use and policy of LAs in England over the next twenty to thirty years (the lifetime of lighting units). Similar choices will face LAs outside of England as well. While LEDs, integrated with CMS, offer highest potential for a transition towards lower-carbon forms of street-lighting, various uncertainties continue to circulate. From a research perspective, this also creates a more pressing need for engagement, but also an opportunity for impact and intervention. The relationship between lighting and society is an interesting emergent area of social science research. Issues of affectivity and lighting (Edensor, 2013a), lighting design and the city (Ebbensgaard, 2014), lighting and landscape (Morris, 2011) and cultures of electric light (Nye, 2010) are among some of the key emergent themes. Questions of technological change in lighting and these social components of light have not yet been closely connected in a contemporary setting, despite the strong historical exploration of this (although see Nye's chapter on 'greenouts'). The findings of this report suggest the requirement for more detailed explorations of the relationship between changing public lighting technologies and the everyday use of infrastructure, and, crucially, the requirement that this research has a policy-orientation, in order to not miss this opportunity to influence this key moment of technological innovation.

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