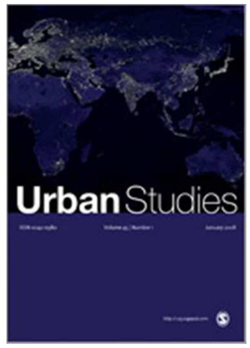

The smart grid as commons: exploring alternatives to infrastructure financialisation

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The smart grid as commons: exploring alternatives to infrastructure financialisation

Abstract

This paper explores a tension between financialisation of electricity infrastructures and efforts to bring critical urban systems into common ownership. Focusing on the emerging landscape of electricity regulation and e-mobility in the United Kingdom (UK), it examines how electricity grid ownership has become financialised, and why the economic assumptions that enabled this financialisation are being called into question. New technologies, such as smart electricity meters and electric vehicles, provide cities with new tools to tackle poor air quality and greenhouse gas emissions. Electricity grids are key enabling infrastructures but the companies that run them do not get rewarded for improving air quality or tackling climate change. UK government regulation of electricity grids both enables financialisation and forecloses opportunities to manage the infrastructure for wider environmental and public benefit. Nonetheless, the addition of smart devices to this network - the 'smart grid' – opens up an opportunity for common ownership of the infrastructure. Transforming the smart grid into commons necessitates deep structural reform to the entire architecture of infrastructure regulation in the UK.

Keywords: Economic development, environment/sustainability, financialisation, governance, smart grid

Introduction

This paper draws together debates on the financialisation of infrastructure and the urban commons. Recent work on urban commons proposes bringing infrastructure into common (often localised) ownership, to pursue a balance of economic, social and environmental outcomes (Chatterton, 2016; Cumbers, 2015). In contrast, the drive to make infrastructure an investable 'asset class' (Inderst, 2010) shows how infrastructure can be 'financialised' so that cash revenues are prioritised over all other potential outcomes (O'Neil, 2016; Webb, 2014). This tension between the needs of global finance capital, on the one hand, and social and environmental outcomes on the other, poses the question whether commons based models of urban infrastructure ownership might be more compatible with urban sustainability. However, urban commons research has not gone far enough in challenging the economic assumptions that underpin financialised ownership models; nor has it justified *why* the management practices associated with commons might deliver a more balanced set of outcomes. This paper will explore these underpinning economic rationales using the example of electricity infrastructure, and the transition to electric vehicles in cities.

We begin with an investigation of the urban commons, showing that urban infrastructures in particular have been a focus of re-commoning. We propose commons approaches to infrastructure need an explicit analysis of property rights. We then explore the 'problem' of infrastructure economics and how it has underpinned the financialisation of electricity grids in the United Kingdom (UK). We argue that financialisation forecloses pursuit of positive externalities. We then explain our empirical focus on e-mobility in cities, before presenting case material which shows how an infrastructure congestion problem can serve to either deepen financialised modes of provision, or provide an economically grounded rationale for commons based management models.

This empirical case addresses how air quality pressures are leading to car electrification in UK cities. Vehicle fleet electrification can improve air quality, but if the electricity grid cannot take the volume of new load this implies, then transport electrification and by extension air quality management suffer. However, electricity grids are owned by international finance capital, which has no reason to prioritise investments that contribute to urban air quality outcomes. Is it just the financialised ownership model that needs to change? Or, instead, the entire regulated revenue structure that supports electricity grids across the world as well as the economic assumptions that underpin that structure?

Defining the urban commons

There has been a recent resurgence of interest in 'the commons' in critical urban studies, a political imaginary that potentially could allocate public goods and infrastructure resources more equitably than [financialised] neoliberal urbanism (Chatterton, 2016; Enright and Rossi, 2018; Harvey, 2011). When exploring commons scholarship, it is important to see a spectrum between economistic interpretations and socio-political definitions. Economistic interpretations develop from a critique of the neoclassical economic literature on public goods; the concept of the commons is applied to ecological common goods such as fisheries, forests, and clean air, where efficiencies and public benefits can be derived from shared governance (Quinn *et al,* 2010). Collectively known as property rights approaches, these studies have had a substantial influence on the natural resource management field (Ostrom, 2010). Increasingly however, the concept of the commons has been applied to the production and distribution of resources in urban space, such as public transit systems, infrastructure, and parks (Foster, 2011). This is where the definition begins to blur into socio-political discourse on connected social struggles, and post-capitalist provision (Chatterton, 2016). For example, when referring to the 'commonwealth', Hardt and Negri (2009) include cultural and socially mediated commons produced by cities. In this paper, we operate at the property rights end of this spectrum and explore whether commons approaches to urban infrastructure can find legitimacy even within a neo-classical framing.

Using a commons/common pool resource approach to urban infrastructure, resists the reduction of governance options to a binary between private and public expenditure. This binary pits neo-liberal enclosure, privatisation and, ultimately, financialisation, against rigid state systems of provision. Instead, the emphasis is on designing hybrid forms of collective provision around which community and civic actors might mobilise. The normative aim of 'commoning' is to create localised institutions of commodity or infrastructure governance, often through negotiation with the state hierarchy (Harvey, 2011; Cumbers, 2015) and with a strong de-commodification theme (Bakker, 2007; Gerber and Gerber, 2017).

Civic commons research has investigated, amongst other forms of infrastructure, water (Bakker, 2007), public space (Radywyl and Biggs, 2013), broadband access (Rao and Parikh, 2003), and energy systems (Becker *et al*, 2016; Wolsink, 2012). This research has examined the *commoning* of such systems as a bottom-up response to the various enclosure, tolling, and financialisation processes that characterise contemporary infrastructure governance (O'Brien and Pike, 2015; O'Neill, 2013). Such contributions often present commoning, as a pathway towards multiple social and environmental goals (Frischman, 2005; Hall *et al,* 2016). For example, Becker *et al* (2016) investigate the social movements that have led to re-commoning of energy infrastructures in Germany (also Hall *et al*, 2016; Moss *et al*, 2015). They highlight the role of urban social movements in re-configuring infrastructure governance as well as the political drivers of institutional change. Many of these studies, however, remain at the socio-political end of the spectrum, where researchers view commoning as a "larger collective political experience, and as a way out of a life defined strictly by the market and the state" (Huron, 2017 p.1063). Because the urban research on commons has largely remained at the socio-political end of the spectrum, the economic assumptions at play are rarely challenged on their own terms.

Such terminologies are important, because they underpin the institutional design of urban infrastructure systems (Mirrlees-Black, 2014). They are the basis on which economists tasked with their governance make decisions (Earle *et al,* 2016). Assumptions about the economic characteristics of individual infrastructures and their property rights shape how they have become financialised, and the institutions that have been built around them to enable that financialisation (O'Neil, 2016; Helm, 2009; Vatn, 2007).

Reasoning within neo-classical terminology has proved extremely fruitful in the natural resource management field, where property rights scholars have demonstrated that close attention to institutional design affects how agents behave towards the finite resources in question (Ostrom, 2006; Bowells, 1998); the assumptions we make about individuals, affects their willingness to co-operate (Vatn, 2007). Broadly, it shows that marketised incentives lead to individual utility maximisation behaviour, while communal rule systems lead to enhanced co-operation.

If the same is true for urban infrastructure resources, then financialised ownership structures, whose rationale is generally grounded in neoclassical utility-maximising economic theory (O'Neil, 2016; Arnsperger and Varoufakis, 2006), would design rule systems that reproduce and re-enforce market based incentives. If different assumptions were made about the resource in question and different theories of individual behaviour applied, then different behaviours might be rewarded, reinforced and produced. This might include commons based models; but if this commoning is to be seen as an alternative to privatisation and financialisation, it should have some economic as well as socially normative rationale. Put simply, if we assume that infrastructure is more than a simple commodity and design systems of ownership and governance that reflect that change, we might achieve different outcomes.

Property rights and infrastructure economics

In identifying the economic rationale underpinning infrastructure financialisation, it is helpful to revisit some key assumptions within neo-classical economics. Samuelson (1954) divided goods into two types: private and public. Pure private goods are simultaneously rival (if individual A is driving a car, individual B cannot drive that car) and excludable (if individual B drives individual A's car without permission they can be excluded from doing so). Public goods, on the other hand, are non-rival and non-excludable (Individuals A and B can both benefit from national defence without their consumption of sovereign safety being reduced, and as sovereign citizens cannot be excluded from doing so). This division allowed neo-classical economics to estimate the optimal level of public expenditure, assuming that private goods exchanged in free markets always discover 'optimal' prices. Public goods are services where markets do not exist or are impossible to create, and so need to be supported by taxation.

Infrastructure is often characterised as a public good (Helm, 2013), but the dichotomy of pure private and public goods does not bear closer scrutiny: individuals and institutions can organise to consume small scale non-rival goods which, in turn, can be made excludable. Buchanan (1965) dubbed these 'club goods', a pertinent example being a 'city car club' where the club membership shares a pool of vehicles that non-members can be excluded from. Buchanan proposed the characterisation of a good depends not on its innate qualities, but on the social rule systems (institutions) that are created to govern it.

V. and E. Ostrom (1977) identified a fourth type of good known as a 'common-pool resource' and refined the terminology. Rivalry became 'subtractability' because the utility of goods is reduced at different rates depending on use intensity or congestion (also Brown *et al,* 2014). Excludability was also conceived as a matter of degree. Common pool resources like a fishery or agricultural water table have complex subtractability and excludability characteristics. They can be overharvested and access may be based on a basket of historical rights claims. Finally, 'club goods' became 'toll goods' as they can be provided collectively by municipal/local councils as well as private clubs.

The category of 'common-pool resource' (see, e.g., Ostrom, 2010, p. 645) has had a huge impact on the practise and study of natural resource management problems, highlighting the power of communal ownership and co-produced rule systems particularly for small-medium sized natural resource systems. A key ideological division emerged between those who followed Ostrom in arguing that polycentric governance, co-operation and institution building could effectively manage common-pool resources, and subscribers to Hardin's (1968) 'Tragedy of the Commons' argument. Hardin used a common grazed pasture example, where more and more commoners add more and more grazing animals until the pasture is exhausted. This Hardin argued, meant common-pool resources are best protected when higher level authorities either regulate the resource, or assign and enforce private property rights to prevent over exploitation (Quinn *et al,* 2010). In an assessment of the respective merits of the two arguments, Coase (1960) argued that the private property approach was more efficient at managing externalities and spillover effects.

Here we are directly concerned with the division between the private property approach to managing externalities proposed by Coase, and the polycentric commons approaches advocated by Ostrom. Ostrom argued that common ownership of the resource in question, along with a series of institutional design principles, can find effective ways of both controlling over-exploitation and managing externalities (Ostrom, 2010; 2010a). The question is, whether the same is true for urban infrastructure systems as for natural resources?

In contrast to natural resources, infrastructure systems have received little attention from property rights scholars. In part this is due to three problematic characteristics of infrastructure which make analysing it through a neo-classical lens extremely problematic (Brown *et al*, 2014), and often attract analysis to the role of the state in provision. These three problems are explored below using the operating example of the UK electricity system and its associated infrastructure.

Three problematic characteristics of infrastructure: the case of UK electricity systems

The first problem is infrastructure's public good characteristics, i.e., degrees of non-excludability and non-rivalry, which necessitate different degrees of state intervention as private levels of provision are likely to be below optimum (Helm, 2010; Little, 2005). The second problematic characteristic is the natural monopoly tendency of infrastructure (Helm, 2010; 2013). Natural monopolies arise where there are large sunk costs and increasing economies of scale (Brown *et al*, 2014). Such scale economies lead to few or single providers which have absolute power over pricing access to essential services, and therefore the state steps in to regulate these prices (Helm, 2013). Further problems arise in ensuring these prices cover investment, deepening the state's role as a contract provider (Helm 2010).

The third and final characteristic of infrastructure is the externality problem. This problem arises when both positive and negative spillovers exist, but are difficult to price directly into infrastructure provision. For example, it is difficult to charge a firm for positive externalities such as labour productivity gains from healthy workers arising from improved sewerage provision, or to value the climate externalities of a new road investment without carbon pricing. However, since net infrastructure spillovers are generally accepted to be positive (Esfahani, and Ramírez, 2003), it is beholden upon the state to determine the optimal level of provision by accounting for these externalities (Helm, 2010; Brown *et a*l, 2014).

The first two problems can be solved by the direct state provision of infrastructure funded through taxation, or by allowing private provision with some form of consumer protection from monopoly pricing (Helm, 2009). The question of whether and how privatisation should occur for network (i.e., urban pipe and cable) infrastructures rests on whether a legitimate institutional regime can be constructed to exclude non-paying users, but cap user charges at an acceptable level (Helm, 2009; Torrance, 2008).

The problem of how to manage monopoly infrastructure pricing under private provision was salient during the liberalisation and unbundling of the UK electricity system (Meek, 2014). For electricity this meant the separation of the system into competitive markets for generation (wholesale) and supply (retail), and regulated monopolies for transmission and distribution networks. This resulted in a liberalised and unbundled market structure.

Assessing the economic characteristics of each part of the system in turn allowed consideration of which elements comprised which type of economic good. Thus generation and supply were classed as private good commodities (Rutledge and Wright, 2011; Kotchen and Moore, 2007). A kWh of electricity is both excludable, in that it can be metered, and rivalrous, in that one's neighbour cannot consume the same energy and more generation must be added to the system to satisfy their demand. This led to the creation of wholesale markets for generation and retail markets for supply (Rutledge and Wright 2011; Lockwood *et al*, 2016). The enabling infrastructure, i.e. the high voltage transmission system and low voltage distribution networks were cast as a toll good, in that they are easy to exclude users from, and the marginal cost of extra use (rivalry/subtractability) was low. This process of parcelling up the electricity system for privatisation required an institutional regime which had to manage the three 'problems' of infrastructure economics outlined above.

The first problem of public good characteristics (excludability) was already dealt with by metering and billing. However, the second, (the control of monopoly pricing) resulted in the regulation of what grid companies could charge to consumers. This price control was based on the RPI-X formula, which allowed revenues of grid companies to rise with the Retail Prices Index (RPI, similar to consumer prices index) minus 'X' an efficiency metric agreed between the networks and the regulator. Almost all grid companies' revenues are based on this formula. This means the 'balance of risk and reward for regulated companies is determined almost entirely by the nature of the RPI-X regulatory regime, and those companies react to that regime rather than to market opportunities' (Lockwood 2016, p. 112). Energy sector research criticises the RPI-X model for a lack of innovation incentive (Müller, 2011; Bolton and Foxon, 2011). While the new (2014) UK regulatory settlement known as RIIO (Revenue=Incentives+Innovation+Outputs) endeavours to better reward innovation, another underpinning institution of network regulation, the regulated asset base, or RAB model, remains relatively unchanged (Wild, 2017) and certainly unchallenged by an urban studies community.

The RAB model is a state guarantee that ensures networks will be able to repay the finance they need to continue their activities (Stern, 2014). It allows the cost of servicing investments to be passed onto customers, ensuring the electricity bill payer carries the risk of new investment by the network company (Stern, 2014). This RPI-X with RAB model has enabled, incentivised, and stands as a global 'example' for the privatisation and financialisation not only of electricity networks but also of gas, rail, airports, communications and water infrastructures (Stanley, 2011; Mirrlees-Black, 2014). This institutional regime makes the investment of private capital in infrastructure a relatively low risk proposition. It has led the ownership of UK grid infrastructure to include transnational firms, such as JP Morgan, Cheung Kong Group, and Berkshire Hathaway. The continuing financialisation of these assets is demonstrated by Macquarie''s recent acquisition of a 61% stake in a gas distribution grid serving 11m homes in the UK (Dummett and Salvaterra, 2016). Helm, (2009) argues that the RAB model incentivises financialisation by rewarding companies for debt mortgaging of infrastructures over operational efficiencies; meaning the gains from financial engineering can easily outweigh those from better network management (Helm, 2009;). Wild (2017) demonstrates that small (i.e. 0.1%) variations in regulatory assumptions over debt and equity costs can lead to network profits/losses of tens of millions irrespective of the actual performance of the network business.

This institutional regime of the RPI-X and RAB model imperfectly deals with the first two problems of infrastructure economics, but does almost nothing to reward network companies for the multiple externalities which accrue to different stakeholders in different systems. These regulated revenues do not reward the pursuit of positive socio-environmental or economic externalities that benefit cities (Hall and Foxon, 2014). These positive externalities may outweigh the financial benefits that accrue to the infrastructure owner, but since the RPI-X and RAB model do not capture them, infrastructure programmes that would otherwise generate net gains in terms of public health, environmental protection etc., are marginalised in favour of maximising returns to finance capital (O'Neil, 2016; Webb, 2014).

The potential of smart grid investments to enable these positive externalities has not escaped the attention of urban activists, who in several cases have 're-communalised' (Fei and Reinhart, 2014) grid infrastructures by taking them into municipal or civic ownership. They have done so to both harvest the traditional revenues available, *and* pursue the positive externalities that smart grid investments can confer (Becker *et al*, 2016). However, taking grids into communal ownership may allow some re-direction of earned revenues, but it does not change the governing institutions of the infrastructure i.e. the RPI-X and RAB model. Re-communalising means bringing into communal (usually municipal or co-operative) ownership, whereas re-commoning would mean a partial de-commodification. Any re-*communalised* grid may be forced into the same financialised calculus that drives corporate grid managers resulting from an unchanged institutional regime.

Although the importance of urban politics of smart grids have been critically examined (Bulkeley, et al 2016, Zhou and Matisoff, 2016), urban and infrastructure studies have yet to question whether the underlying institutional resource regime, i.e., the RPI-X/RIIO/RAB toolbox, is fit to secure multiple positive externalities enabled by smart grid investments. Nor have commons scholars spent sufficient time coming to terms with the property rights implication of these institutional regimes.

Kunneke and Finger (2009), do explore the property rights assumptions that underpin urban infrastructure governance. They point to liberalisation as a process of institutional fragmentation, competing interests, and mixed incentives; giving rise to complex co-ordination issues. They argue this is more akin to common-pool resource governance than toll good operation. Künneke and Finger (2009 p.5) further argue that electricity grids are better conceived as common pool resources because:

1. Excludability of access maybe technically possible but politically unfeasible.
2. Once access is gained it may be difficult to determine how users appropriate services.
3. *Access is open (after a fee)* yet these are services from which each individual user takes benefit at the expense of others; i.e., there is rivalry in the consumption.

In summary, the institutional regime built around electricity distribution infrastructures in the UK stands as an international 'exemplar' of how to financialise network infrastructures. This regime is legitimated by property rights assumptions that cast the grid as a toll good, and create regulated charging structures to prevent monopoly pricing. However, it has not solved the problem of multiple externalities, such as economic development, carbon control, and air quality management, which are conferred by smart grids on cities. The natural resource management community has often found common property regimes are better able to manage resources for complex outcomes. Given the multiple positive externalities associated with smart grid development in cities (Hall and Foxon, 2014; Webb, 2014), the research question is: Would the positive externalities of smart grid infrastructure benefit from a property rights settlement that assumed they constituted a common-pool resource as opposed to a toll good?

Methods

A three phase methodology was used. Phase 1 consisted of case study selection. We selected urban e-mobility (the transition to electric car use) as a theory-confirming case (Yin, 2011) for two reasons. Firstly, there is evidence suggesting the presence of high positive externalities/spillover effects associated with e-mobility at the urban scale in respect of air quality, economic development and carbon control (Hall *et al,* 2017). Because UK cities do not control energy infrastructures but do capture spillover benefits of e-mobility, one might expect cities to be increasingly interested in electricity grid governance. Secondly, the capture and maximisation of spillover benefits often enrols multiple parties in negotiation and re-negotiation of boundaries, access and resource use behaviour (Ostrom, 2010). Thus the need of e-mobility transitions to enrol smart grids, drivers, city governments and network companies manifestly demonstrates a 'complex co-ordination issue' which Kunneke and Finger (2009) claim as a key characteristic of common pool resource dilemmas.

Phase 2 involved 22 semi-structured interviews with 26 individuals. Participants were selected with direct experience of electric vehicle infrastructure management in the UK. Questions were formed around the barriers and enablers for increased electric vehicle penetration in cities with a specific focus on infrastructure governance. The sample comprised: 4 interviewees from city governments, 3 vehicle manufacturers, 2 auto industry and public partnerships, 3 charge infrastructure providers, 3 energy utilities, 2 academics, 2 energy system regulators, 2 fleet managers, and 1 government department.

In phase 3, two expert focus groups were undertaken, designed to understand the co-ordination issues and trade-offs involved in different methods of managing e-mobility transitions and infrastructure stress. Focus group #1 comprised: 1 energy supplier, 2 city managers, 1 government sponsored innovation incubator member, 3 academics, 1 charge point provider and 1 infrastructure operator. Focus group #2 comprised: 2 officers of the energy regulator, 3 vehicle manufacturers, 3 academics, 2 charge point providers, 2 energy suppliers, 2 fleet managers, 1 government department, 2 independent energy systems experts, 1 government sponsored innovation incubator member, and 1 auto industry body. The remaining sections report the initial findings of this research.

The role of cities in e-mobility infrastructures

Until recently a common Cost Benefit Analysis has been used to prioritise transport infrastructure spending in UK cities which assessed economic, environmental and social impacts of new schemes (DfT, 2016). Using cost-benefit approaches, the state can comparatively assess competing infrastructure schemes for the ratio of capital costs against other positive and negative externalities. However, since more infrastructure spending power has been devolved to city-regions in the UK (O'Brien and Pike, 2015a), infrastructure assessment has become much more focussed on a single positive externality (spillover effect), that of economic development, as opposed to an assessment of economic, environmental, and social benefits (Mullen and Marsden, 2015). The common cost-benefit framework suitable to public good assessment has been replaced by a hybrid economic development assessment. Following this, new air quality management responsibility and road user charging powers have also been devolved (House of Commons, 2016). In short there has been a series of changes to transport infrastructure governance in cities. These changes have emphasised aggregate private gain over public good gains by focussing on economic development spillovers from transport infrastructure schemes. This replaces the cost benefit approach of travel time benefits weighed against environmental and social impacts.

Until recently those responsible for sustainable transport spending did not have to consider energy infrastructures. However, recent research shows that poor air quality in towns and cities in the UK contributes to over 40,000 premature deaths every year (Royal College of Physicians, 2016). In July 2017 the UK Government published its Clean Air Strategy (DfT & Defra, 2017) as a response to a legal battle over urban air quality. Poor air quality, particularly nitrogen dioxide levels from diesel vehicles in towns, mean that legal limits in many UK towns and cities are regularly exceeded (Boffey, 2016) This 'public health emergency' (House of Commons, 2016) led campaigners to push for concerted government action that has culminated in government placing further responsibilities on cities to find solutions. One proposal is the banning of sales of all new pure petrol/diesel cars by 2040. This demonstrates that air-quality concerns are the primary regulatory drivers for the electrification of passenger cars.

Supporting electric mobility in UK cities has thus far been limited to parking and charging provision; urban transport bodies providing public charge points at strategic locations. This provision has become dependent on grants from central government, leading to uneven coverage across the UK. Cities have been restricted in how they support electrification because parking and charging is the only piece of enabling infrastructure they have control over:

"…at the moment, we are tinkering around the margins, I mean, great, take the Elland Road [Leeds] *Park and Ride, we've got a few charging points there, which is great. If actually every single car on that car park wanted to charge, it wouldn't be able to happen would it? Because the grid wouldn't support it and then that… so, at what point do we start to really worry about that?"*

(Source: City Government Officer, 2016)

"We kind of know what we need, what needs to happen but it's just a question often of getting collective interested parties pointing in the right direction at the right time. Because what's been done in the urban environment so far has been pretty much hopeless"

(Source: Energy Supplier, 2016)

This "hopelessness" is in part due to the fact that, after privatisation and subsequent financialisation of the UK electricity system, cities have almost no influence over the single most important infrastructure for enabling e-mobility, the electricity distribution grid.

Energy systems in urban e-mobility

"So imagine going into any council in the UK and say right tomorrow you are not going to control any of your roads, at all, and what we are going to do is we are going to give it to a private sector company and then they are going to run your roads without any regard to anything you have actually got to say, anything you have got to strategically plan where you are going to build your developments, they are going to charge all your road users irrespective of anything you have got to say, to travel across those roads. And you have got no ability to either control that pricing model or even have a say at the table with regards to development […] People would just look at you as if you were just absolutely bonkers. As a model to drive or even control your strategic assets... you can see why it wouldn't work, and that's effectively what we have got in the distribution network"

(Source: City Government Officer, 2014)

UK cities have no statutory involvement in the governance of electricity infrastructures. Most electricity systems are centralised, built on a model of high capacity plant, connected to infrastructure networks which step down voltages to useable levels for homes and businesses. Electricity, unlike gas, oil products, or solid fuels, cannot be stored. Electricity systems have therefore been built so supply matches demand at any period and system frequency remains within design limits. The addition of vehicle batteries to this system does not change these parameters, it either places more stresses upon them, or offers more flexible ways of fulfilling them, depending on how the vehicle charge cycle is managed. If the charge cycle goes unmanaged this can create problems of 'grid constraint' a congestion of the infrastructure due to the load electric vehicles (EVs) place on these distribution networks:

"…Well the challenge that we've had is that it is very difficult to supply sufficient power for a significant number of vehicles at any one time. In terms our own fleet we have been kind of restricted on most sites two or three electric vehicles, sometimes up to five. But where we've got opportunities in terms of suitability of fleet transition to have say 10, 12 even 20 electric vans operating from one site, we've not been able to do that because we haven't got sufficient power [grid capacity] *at those sites"*

(Source: City Government Officer, 2016)

So for home charging, you know. Clearly there's a number of issues that come out. First it's scale. You'll get a clustering effect of vehicles in certain neighbourhoods and networks. A sort of panel effect, when one house gets one, another house wants to get one too. So you've got a local problem in terms of infrastructure; can that local infrastructure manage the demand at the same time?

(Source: City Government Officer [different to above] 2016)

It is at this point of congestion where the economic assumptions that regard distribution grids as a toll good break down, as the marginal cost of extra consumption by consumers with EVs increases exponentially as the resource becomes congested, In natural resource terms, distribution grids are being 'overharvested'.

"… the effect of the EVs on the grid is, in fact, not only quite high; it's actually going to make things worse and there isn't any mechanism to stop that from happening."

(Source: Energy Supplier, 2016)

The low subtractability/rivalry characteristic of a toll good is no longer fulfilled. If the property right characteristics are re-considered, several strategies may present themselves which could prevent 'overharvesting' of the infrastructure.

In a traditional 'dumb' distribution grid, once consumers have secured access to the network it is impossible to determine whether their consumption contributed to peak levels of congestion, as no individualised time of use data was available. Because of this, the high marginal costs of peak consumption are borne by all users. However, the roll-out of smart grids, comprising smart electricity meters, new network monitoring technology, and new demand side management techniques mean that new opportunities *are* emerging to monitor user demand and manage peak use periods. These new technological enablers fall into two categories, demand side participation and demand side management.

Demand side participation involves a behaviour change by a system user to shift demand to a different time of day. Demand shifting has three main benefits: 1) to help the system operator (National Grid) to keep the system within engineering specifications, 2) to use energy when it is cheapest (usually in periods of low demand or high renewable generation), or 3) when any extra demand would overload the low voltage infrastructure carrying the electricity. Demand response can benefit different parties in the energy system with different incentive structures that do not always align.

"…For example, if you are contracting services with the National Grid you need to pay attention to what kind of services you are contracting with a DNO[1] because you can't offer the same service or the same resources aggregated to both of them."

(Source: Energy infrastructure provider, 2016)

This is a further characteristic that suggests electricity grids are common pool resources; many parties make different claims on each other at different times which lead to complex co-ordination issues, as suggested by Kunneke and Finger (2009).

If distribution grids were understood as a common pool resource problem there would need to be monitoring infrastructure in place to police extraction (Ostrom, 1990). This has not been possible until recently; traditional meters in homes and small commercial premises only measure aggregate use, not when that use occurs. This means that most domestic and small commercial consumers are settled on a profile, and the characteristics of their resource extraction cannot be monitored. Smart metering changes this, as it allows consumers to be half hourly settled, i.e., they can be billed for exactly what they use and when they use it:

"So with the half hourly settlement, if you have a smart meter we would be able to charge, put your unit rate on a half hourly basis. So you could do that, but actually the costs that will be incurred in terms of the network costs and the actual wholesale costs of that. So the network and wholesale cost we would still being billed as if they were profile customer. ***Whereas with elective half hourly settlement, and in future mandated half hourly settlement, the charges will start to become more reflective."***

[1] Distribution Network Operator, the company responsible for the local, low voltage grid.

(Source: Energy supplier 2016; emphasis added)

What is being described above is the need for consumers to have a smart meter *and* 'elect' to choose half hourly billing. Being more 'reflective' refers to cost reflective pricing. The problem with cost reflective pricing for an EV consumer, is that while the distribution network companies *could* remunerate electric vehicle consumers for charging during periods of low network use (i.e. during the night) it is the supplier/retailer who has control over the billing process. With different households having different suppliers and switching at increasing rates, it is extremely difficult to construct a remuneration regime for consumers to respond to, if the goal is to better utilise the grid resource (Distribution Network Operator officer focus group responses). An additional disincentive is the monetary value of flexibility to single consumers:

"It's very difficult to see why the customer would be incentivised to do that [load shift] *unless there was a significant financial upside for them to do that. Which there wouldn't because power with electricity is cheap and unless there was some kind of model that every time you flatten your peak at breakfast time, we'll give you fifty quid…"*

(Source: Energy supplier, 2016)

This suggests that, unless the financial rewards/penalties for good/poor demand side participation were substantially higher than the marginal cost of use, it is unlikely individual EV consumers would find behaviour change worthwhile. They could co-operate with the grid company without reward, but as Vatn (2007), Ostrom (2006), and various experimental and ethnographic studies demonstrate (i.e. Ross and Ward, 1996), the marketised relationship with the private corporate provider does not motivate selfless co-operation.

This is why we are interested in commons approaches to infrastructure use. Monetary rewards to rational individuals are small and complex to administer. Another approach is to remove the price incentive altogether and operate grid management on a co-operative basis. This is technically possible using remote interruption of vehicle charging during peak times to protect the grid from overload.

This changes the property rights relations with the infrastructure provider from a simple toll fee for access, to a managed regime requiring consent and co-operation. However, moving from a simple fee for access model to a model requiring more user engagement is difficult:

"I'm aware of the impact on the grid, your average consumer won't care and couldn't care less. Why should they? So there's a potential ticking time bomb with that which needs to be solved. And one way to solve it is […] adjust the energy flow. Either reduce it or even make it bi-directional so it can supply energy at given times, which, will consumers be happy with? Given the large amount of money they paid for the very expensive battery in the car, and actually very little financial return for the energy…?

(Source: City Government Officer, 2016)

The problem with hardwired demand side management (DSM) is that consumers have no incentive to allow for flexibility if is it is not remunerated through the bill unless it is part of a wider consensual rule system. A consistent theme in smart grid innovation trials has been the need to closely engage consumers and provide detailed information on why the network is in need of closer management (Fisher *et al*, 2015; Frontier Economics, 2015). This is because the infrastructure constraint issue has an extremely stubborn geography:

"It's not an issue of total demand […], it's a question of managing peaks, but it's worse than that. It's also about managing street by street, house by house…"
(Source: Vehicle Manufacturer, 2016)

The need to enrol communities on such a tight geography, and provide channels of communication which either drive behaviour change or legitimise direct intervention in the charge cycle, may be successful in small, well-funded trials, but they are not compatible with the current relationship of millions of householders with their distribution network operator. This need for personal communication, localised co-operation, and behaviour change in favour of resource conservation represents many of the characteristics documented by common pool natural resource management scholarship (Vatn, 2007; Künneke and Finger, 2009; Quinn, 2010).

Discussion and conclusion

This research explores a tension between financialisation of electricity infrastructures and efforts to bring critical urban systems into common ownership, using the UK electricity grid system as an exemplar. The institutions governing the distribution networks, principally the RPI-X and the RAB model, were designed for the private provision of a toll good, beyond the reach of city governments. This model is unable to account for the positive externalities of e-mobility in cities, or enrol multiple resource users in new governance structures. This is because under a RAB model, with its tendency towards financialised ownership, the beneficial owners of the network do not capture positive externalities that include air quality benefits [principal in this case], greenhouse gas mitigation, economic development effects and the ability to better optimise wider decentralised energy systems of cities (Webb, 2014).

This research demonstrates that new technologies, principally smart metering and demand response applications, offer new opportunities to enrol customers in the management of the grid resource. Given that grid constraints manifest on a 'street by street' basis, the geographies and communities of electricity distribution become much more important in the future management of the resource. The need to co-ordinate these assets to address the 'public health emergency' of air pollution in UK cities, and a wider drive to strategically manage energy assets across cities, to maximise positive externalities, is drawing municipalities and communities more concretely into the issues of grid management.

There has been recent interest amongst UK local authorities in taking distribution grid assets into municipal control to deal with some of the issues identified above. For example, Gateshead City Council has purchased part of the distribution network from the incumbent grid company to support a new combined heat and power smart energy centre (Gateshead City Council, 2016). This is a small example of re-municipalisation of elements of the UK distribution network, which is becoming more attractive to UK cities as grid access and management becomes the major barrier to distributed energy system development (Core Cities, 2013). In Germany and the US there have been wholesale re-municipalisations of distribution grids (Fei and Rinehart, 2014). Such efforts at re-communalising represent what some in the urban commons community would see as a positive step towards de-commodifying critical infrastructure. However, taking a property rights approach demonstrates that beneficial ownership of the infrastructure resource by a municipality does not make for infrastructure as commons. What matters is how inclined a new owner is to manage the infrastructure resource as an urban planning tool to maximise positive externalities (O'Neill, 2016), and thus move away from a pure toll good relationship by taking a more pluralistic approach to value.

We asked: would the positive externalities of smart grid infrastructure benefit from a property rights settlement that assumed they constituted a common-pool resource as opposed to a toll good?

At this stage there appear to be two pathways that the institutional governance of smart grid transitions can take. These two pathways are to push the resource towards further enclosure and cost-reflective user charging, thus moving toward a private/toll good hybrid model, and deepening the monetisation of behaviour change and the calculus of financialisation. The second pathway involves using these technologies to manage the grid as a toll/common-pool hybrid by enrolling new actors and new governance structures to manage the resource to maximise positive externalities. Doing so implies complex co-ordination and co-operation issues that are more akin to common-pool resource management problems. The latter option would require an entirely new institutional regime to replace RPI-X and the RAB model with something much more compatible with common pool resource design principles (Ostrom, 1990; 2010).

Smart meters with half hourly settlement, consumer participation, and cost reflective pricing could very well enable grid operators to charge the marginal cost of provision to those who use the grid at periods of congestion. This would fit very well with a neo-classical rational economic actor approach, which would stipulate the closer to a private good the resource can become the more efficiently it can be managed through a price signal (Coase, 1960). Cost reflective pricing of a toll good is much more compatible with the existing financialised ownership structure of many distribution network operator companies. However, focus group participants in this research highlighted ethical and distributional concerns over the impact of this type of pricing on vulnerable consumers who may not have the ability to switch load and may get penalised by high peak charges. This echoes Kunneke and Finger's (2009) point that while it may be technically possible to move to a more private logic and marginal cost approach it may be politically unfeasible due to universal service concerns.

The second pathway, managing the grid as a common-pool resource, is arguably more complex in that it involves finding a mix of institutional measures and consensual rule systems which prevent over harvesting of the resource by deploying demand-side management measures and incentivising behaviour change with little or no market exchange of value. This would mean constructing an entirely new governance regime that enrolled consumers in new relationships with the infrastructure provider through behavioural change *and* consensual rule systems. It is unclear whether the re-municipalised and communalised ownership structures emerging through the various examples of commoning seen across multiple OECD nations (Fei and Reinehart, 2014; Becker, *et al* 2016) are more compatible with this approach if the underlying institutional regime remains unchanged. However, it is clear that accounting for the multiple spillover benefits of smart grids in cities, not least in enabling e-mobility, does require a re-evaluation of property rights claims within urban infrastructure provision. This re-evaluation would threaten the existing regime, the sunk costs of investors, and the long term stability of the invested capital that feels secure under the

RAB model. This cannot be taken lightly as it would likely increase the cost of capital, and therefore increase energy bills across the nation, if a regulator were even seen to be considering such a radical change to the system (Stern, 2013). It is this weight of incumbent interests, committed over such long timescales, that any more spatially compatible proposal for grid management would have to contend with.

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