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Values in the Smart Grid: The co-evolving political economy of smart distribution

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HIGHLIGHTS

- Smart grid investments can benefit municipal economic development.
- Drawing on urban political economy we describe these values.
- New values alter the smart grid investment problem.
- New integration of urban policy and DNOs are proposed by this research.
- Socio-technical approaches are enhanced by urban political economy and vice versa.

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ABSTRACT

Investing in smart grid infrastructure is a key enabler for the transition to low carbon energy systems. Recent work has characterised the costs and benefits of individual "smart" investments. The political economy of the UK electricity system, however, has co-evolved such that there is a mismatch between where benefits accrue and where costs are incurred, leading to a problem of value capture and redeployment. Further, some benefits of smart grids are less easy to price directly and can be classified as public goods, such as energy security and decarbonisation. This paper builds on systemic treatments of energy system transitions to characterise the co-evolution of value capture and structural incentives in the electricity distribution system, drawing on semi-structured interviews and focus groups undertaken with smart grid stakeholders in the UK. This leads to an identification of municipal scale values that may be important for business models for the delivery of smart infrastructure. Municipalities may thus pursue specific economic opportunities through smart grid investment. This supports recent practical interest in an expanded role for municipalities as partners and investors in smart grid infrastructures.

1. Introduction

".....the inherent economic viability and wealth of a city is intrinsically linked to its capacity to supply heat and power and the infrastructure, whether that's roads, telecommunications or energy infrastructure...." (Interviewee, 2014).

Whilst there is no universal definition of what makes an electricity distribution grid "smart", Xenias et al. (2014) define the main features of a smart grid as an energy network that can: manage embedded suppliers, communicate between the producers and users of electricity, utilise ICT to respond to and manage demand, and ensure safe and secure electricity distribution. Current electricity distribution networks in the UK do not incorporate these features and so (save some demonstration projects) may still be regarded as forming "dumb" grids that are maintained to accommodate one way power flow and ensure security of supply (Balta-Ozkan et al., 2014).

Smart Grids form a key part of the transition to low carbon energy systems. The UK's energy regulator Ofgem has estimated

Abbreviations: DCPR, distribution price control review; DE/DH, distributed energy and district heat; DNO/DSO, distribution network/system operator; DSR, demand side response; DUoS, distribution use of system; ESCo, energy service company; GVA, gross value added; kV, kilovolts; LEP, local enterprise partnership; NUP, new urban politics; PPA, power purchase agreement; RE, renewable energy; RIIO, revenues incentives innovations outputs; RPI-X, retail prices index – "X"; SME, small to medium enterprise

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that meeting electricity system decarbonisation targets compatible with the UK's Climate Change Act (2008), would require up to £32bn of investment in distribution assets by 2020 (Ofgem, 2010a). Some recent scholarship has analysed the costs and benefits of individual "smart" investments (De Castro and Dutra, 2013; Faruqui et al., 2010; Jackson, 2011); yet many of these approaches analyse only those economic values that can be captured by the utility deploying the technology. As such the "benefit" element of the cost benefit analysis for smart grid investment, is bound to those revenues which accrue to the investing utility (Giordano et al., 2012). However, there are geographically specific values that accrue to non-traditional actors from smart grid deployment. In this paper, we argue these values could be captured under different business models for smart grid investment. We demonstrate the wider benefits of smart grid investments by examining the local economic development benefits that can accrue to city-regions. We draw on two literatures to describe the current mismatch between traditional and alternative valuations of the smart grid. These are socio-technical transitions literatures, and urban political economy. Bringing these two literatures together with empirical evidence from interviews and focus groups, we show how new business models for smart grid investment can be proposed with a greater role for municipal governance.

This paper is structured as follows: Section 1.1 describes the emergence of a co-evolutionary understanding of large system change. We link this to the need for an understanding of urban political economy to underpin our analysis, given a new interest in energy infrastructure at the city-regional scale. This leads to our research questions. Section 2 sets out the methodology for the study. Section 3 begins with a description of the traditional appropriation of value for UK smart grid investments, followed by substantive analysis of the economic values that smart grids confer on cities. We then propose a new reading of the smart grid investment problem, and utilise this analysis to extend our understandings of value in the smart grid. We conclude with policy implications and by arguing that urban economic development resources may find smart grid infrastructures productive avenues for investment.

1.1. Co-evolution of technical and social elements in the UK's distribution infrastructure

The liberalisation and privatisation of the UK energy system led to competitive markets being created for generation and supply whilst transmission and distribution functions were moved to a regulated approach (Bolton and Foxon, 2013). The complexity and interconnectedness of these liberalised energy systems has led to a broad acceptance that they exhibit traits of "large technical systems" in that they are complex, heterogeneous systems consisting of physical assets such as machinery, ICT, and the built environment, alongside non-physical artefacts such as companies, regulations, investors, societal practices and politics; each of which are interdependent (Hughes, 1983; Joerges, 1998; Geels, 2006). Socio-technical transitions approaches describe these large technical systems as multi-layered interactions between socio-technical landscapes, regimes and niches (Verbong and Geels (2010); Geels, 2004). A further literature on technical innovation systems is typically focussed on individual innovations and the processes by which they evolve within particular social and economic contexts (Hekkert et al., 2007; Bergek et al., 2007). Innovation approaches describe how technologies and practices can exhibit parallels to biological evolution such as variation, selection and retention. Both approaches are complementary (Markard and Truffer, 2008; Foxon, 2011) and allow researchers to characterise complexity in large systems and theorise ways to manage system transitions that are more compatible with sustainable futures (Kemp and Rotmans, 2005). Foxon (2011) incorporates these approaches with evolutionary approaches to economic change, to propose a "co-evolutionary" framework for analysing a transition to a low carbon economy; this approach "seeks to identify causal interactions between evolving systems" (Foxon, 2011, p. 70). These "systems", (technologies, institutions, user practices, ecosystems and business strategies) co-evolve to produce particular system trajectories that are more or less aligned with low carbon futures. Co-evolution operates on the basic ecological premise that two or more populations of entities can influence each other's evolution (Murmann, 2003, 2013; Norgaard, 1994). As such Foxon (2011) follows Nelson and Winter (1982) and Freeman and Louca (2001), describing these systems as subject to their own internal evolutionary dynamics, but as also being affected by evolutionary dynamics in the related systems. These elements of the system *co-evolve* because they have significant causal impact on each other's ability to persist (Murmann, 2003; Foxon, 2011). As such, studying these interactions and co-evolutionary processes in infrastructure systems such as electricity distribution, can facilitate a deeper understanding of the actual processes that lead to change, offering a greater chance of successfully orienting these systems towards low carbon futures.

Recently co-evolutionary approaches have described elements of the energy system. Bolton and Foxon (2013) analyse the co-evolution of energy distribution regulation in the UK, with the business strategies of distributed energy schemes. They find that a regulatory imperative, consumers' legal right to switch supplier, constrains the deployment of both individual schemes and aggregated low carbon generation options (Bolton and Foxon 2013). Hannon et al. (2013) analyse the co-evolution of UK electricity supply business models, investigating both traditional utilities and energy service companies (ESCos). Rather than relying on a business model based on distant consumer relations and kWh unit volume, ESCos build close consumer relations and offer final energy services for predefined prices, drawing revenue streams from energy savings. Focussing on supplier business models demonstrates the susceptibility of the energy system to narrow conceptions of energy value. Giordano and Fulli (2012) propose that amended business models for distribution operators and system aggregators could be enabled by smart meters and electric vehicles, and may alter the value capture opportunities in the whole system. They conclude by calling for further research to "capture the disruptive value of new business models and platforms" (Giordano and Fulli, 2012, p. 258). We follow this call by analysing the co-evolution of business model elements of the UK distribution system with institutions at the urban scale, to examine how this may yield new ways of thinking about "values in the smart grid" and how to capture them.

The importance of identifying different business models for infrastructure delivery has been highlighted in the UK Governments National Infrastructure Plan (HM Treasury, 2013). This research directly supports this search, forming part of the iBUILD[1] (Infrastructure Business models, valuation and Innovation for Local Delivery) project (HM Treasury, 2013, p. 98); iBUILD focuses on the city and city-regional scale of infrastructure delivery. Infrastructure business models in particular differ from those associated with the delivery of products and services due to high capital barriers to entry, the difficulties of excludability, their tendency toward natural monopoly, and the complexities of value capture in infrastructure delivery (Bryson et al., 2014). Whilst we recognise the utility of detailing the specific attributes of business models in particular parts of the system after Hannon et al. (2013); we see the need for a definition of *infrastructure* business models. We follow Bryson et al. (2014) in defining these as "The system of

[1] See https://research.ncl.ac.uk/ibuild/.

physical artefacts, agents, inputs, activities and outcomes that aim to create, deliver and capture economic, social and environmental values over the whole infrastructure life cycle" (op cit p. 7).

Our focus on *local* business models, leads us away from a purely socio-technical analysis, as these approaches have hitherto under-theorised the role of space/place in system transitions (Monstadt, 2009; Hodson and Marvin, 2010). Recent contributions have begun exploring links between socio-technical approaches and urban political economy (Hodson and Marvin, 2010; Bolton and Foxon, 2013). We therefore draw equally on urban political economy to analyse the urban or "local" making and remaking of energy infrastructures.

1.2. Cities and entrepreneurial infrastructures

The Localism programme of the UK's Coalition Government has placed the responsibility for elements of infrastructure delivery in the hands of city-regions. This is particularly evident in the suite of City Deals agreed with England's city-regions and Local Enterprise Partnerships (LEPs) throughout 2012–13; the majority of which exhibit strong ambitions for localising financial and governance aspects of infrastructure delivery (HM Government, 2012; Hildreth and Bailey, 2013). The City Deals are one element of a wider programme of infrastructure localisation, which is being linked strongly to the conditions for economic recovery (Heseltine, 2012; HM Government, 2013). At the local level, a partnership of England's eight largest cities outside London has signalled their intent to offer energy supply services, build institutional relationships with distribution network operators (DNO's), eliminate tariff discrepancies and proliferate embedded energy generation businesses (Core Cities, 2013). Similarly, the Greater London Authority is seeking a new form of supply licence to reduce regulatory and institutional barriers to RE schemes, as identified by Bolton and Foxon (2013). This "licence lite" is cited as a step towards the ambition of the Mayor of London to source 25% of London's energy locally by 2025 (GLA, 2013). These movements form part of a wider urban concern, wherein some cities are beginning to see climate governance as a strategic economic opportunity as well as an environmental imperative (Bulkeley and Betsill, 2013; While et al., 2010).

In a seminal piece on the role of cities in global economy, Harvey (1989) described a shift in the governing logics of cities from "Managerialism" to "Entrepreneurialism". The central contention of this work was that local governments, bereft of the relatively steady employment conditions of Keynesian stimulus and Fordist production systems, are driven by the need to retain local business and attract new firms by deploying the resources of the local state to make their particular place attractive to mobile capital (also Altshuler and Luberoff, 2003). Cities achieve this by differentiating themselves via packages of tax relief, place marketing, sectoral specialisation, and critically for our analysis, infrastructural assemblages (Graham and Marvin, 2001). How urban entrepreneurialism manifests in urban political economy is understood in a number of ways by critical urban theory (MacLeod and Goodwin, 1999). Of most utility to this study is the "city as a growth machine" theory, which explains the construction and behaviour of particular constellations of actors and institutions with stakes in the economic fortunes of a given area. The city as a "growth machine" approach is based on the seminal works of Molotch (1976). Molotch's (1976) contention was that "growth coalitions" are formed by groups of land owners/developers and the local state, as both have much to gain from land use intensification in a given territory. Whilst the original growth machine theory has received close critical scrutiny (Jonas and Wilson, 1999), it continues to be usefully employed by scholars seeking to uncover the causal mechanics of urban phenomena, particularly with regard to local agency in developing urban infrastructures (Kirkpatrick and Smith, 2011; Jones, 2001). For other urban scholars the primacy of land based interests is less critical. Lauria (1997) argues that Urban Regime Theory, as formulated by Stone (1989), and Elkin (1987) can address how different stakeholders in cities emerge around growth interests and municipal governance. Urban regime theory explains urban politics by focussing on how collective decisions about urban development arise. These approaches describe how urban regimes often solidify around inward investment imperatives as opposed to redistributive interests. Whilst these approaches are theoretically distinct, they have been defined under the umbrella term of New Urban Politics (Cox, 1993; MacLeod and Goodwin, 1999; Jonas et al., 2010). This approach can be usefully deployed to understand the agency and strategies of growth actors in particular territories. This identifies a demonstrable group of urban actors that seek to influence the deployment of state resources at different levels to secure competitive advantages for their neighbourhood, city or region. These actors have been variously described as growth coalitions, growth regimes and local economic development networks. Here we use "growth coalitions" from the growth machine approach, which foregrounds land use intensification as a key enabler of urban growth. It is land use intensification and associated pressures on electricity grids that the following analysis demonstrates may be addressed via smart grid development.

The growth machine approach has recently been used to understand how urban elites mobilise to ensure urban growth can be sustained in contemporary capitalist cities under state-induced conditions of fiscal austerity (Hall and Jonas, 2014; Kirkpatrick and Smith, 2011). A particular focus is on the mechanisms through which urban infrastructure is financed in order to revive growth trajectories (Ward and Jonas, 2004; Davidson and Ward, 2014; Jonas et al., 2010). This begs the question as to what role infrastructure provision can play in facilitating urban competitiveness and who benefits from realising it.

Cox and Wood (1997) explain how the structure of energy utilities in the US draws them into local growth politics. In many states and jurisdictions, utilities serve territories as monopolies. It is therefore in the interest of a utility working on a "units of energy sold" business model to ensure residents, commerce, and industry remain within or are attracted to a particular locality. The utilities are to a degree locally dependent (Cox and Mair, 1988) in that their profits are tied to place. The primary role of utilities in Cox and Wood's (1997) analysis demonstrates the importance or energy infrastructure networks to firms looking to relocate, and how the political economy of energy infrastructure can be implicated in wider local economic development networks.

However, in the UK, privatised and mainly multi-national energy utilities operate within a liberalised energy market that is nationally regulated (Bolton and Foxon, 2013). Hence, both generation and supply actors in the electricity system have little or no incentive to participate in local growth activities; securing local growth in a particular place is not incentivised by their "business model" (Hannon et al., 2013); as such they lack local dependence (Cox and Mair, 1988). However, this is not the case for other types of infrastructure such as rail transport (Peters, 2009), toll roads (Torrance, 2008), ports (Daamen and Vries, 2013) or communications (Rutherford, 2005). The acceleration of high speed broadband into local enterprise zones may be seen as an attempt to leverage infrastructure networks as an enabler of urban place based competition for inward investment (HM Treasury, 2011). What has been lacking to date in the UK is an understanding of the values that smart grid infrastructures deliver at the urban scale. We investigate whether smart infrastructure has the potential to facilitate inward investment, unlock sites for development, increase local energy schemes and increase the local tax base.

This analysis combines insights from the socio-technical transitions and New Urban Politics literatures, in order to demonstrate how these values may be realised by local actors; this enables a broader appreciation of the role of space in infrastructure innovation and transitions. It is particularly apposite to do so now, as a number of studies have begun to analyse the circuits of value incorporated in the energy system, and how they might be captured at the local scale. Gouldson et al. (2012) show that 10% of GVA "leaks" out of the Leeds City Region economy to pay the energy bill. Sherwood and Tompt (2013) investigate biomass and solar generation in Herefordshire. They find £909 m of investment opportunity and potential for £130 m/year local revenues. Importantly Sherwood and Tompt (2013) note that there remains "the shadow of whether the existing electrical distribution grid in and around Herefordshire would need substantial development before it could cope with local generation of electricity on the scale envisaged" (Sherwood and Tompt, 2013, p. 36). Further studies have analysed the economic advantages that might induce municipalities to pursue expanded renewables generation such as local employment, reduced future costs of electricity and increased local tax bases (Busch and McCormick, 2014; Heinbach et al., 2014). Whilst many of these studies focus on the proliferation of renewable energy (RE) schemes, the transition to a smart grid is a crucial factor. In order to capture these benefits, a compatible grid infrastructure must exist.

The socio technical systems literature helps us to understand institutions and business models within the national energy system, whilst urban political economy approaches inform us as to why specific constellations of urban actors form coalitions and how they leverage infrastructure investment to promote urban growth. Combining the two enables us to address the questions: what local values are created by transitioning the socio-technical system of electricity distribution to "smart" status? And: what institutional structures and business models can be constructed that capture these values given their attractiveness to local growth coalitions?

2. Methods

These research questions rely on value judgements by stakeholders. As such we utilise a qualitative research design, combining secondary documentary analysis of policy and regulatory literatures with substantive primary research comprising in depth semi-structured interviews and focus groups. We adopted a purposive sampling technique utilising snowball selection. Interviewees were selected that had specific interests in either the distribution network or smart grid, local energy related economic development issues or both. We undertook 3 focus groups and 10 interviews with 17 individuals from across the electricity generation, distribution and regulation sector, alongside municipal stakeholders drawn from across the UK (focussing on Northern England). This included 2 regulatory professionals, 2 project developers, 5 "local growth actors" from municipalities or economic development organisations with an interest in local energy, and 8 distribution network or smart metering professionals. Interviews and focus groups were undertaken both face to face and over the telephone. Interview transcripts were analysed using NVivo to extract themes of value capture and retention from smart grid technologies. We follow Hodson and Marvin (2012) who used a combined approach of documentary analysis and in-depth interviewing as a good methodological fit for undertaking research at the intersection of socio-technical transitions and urban political economy. The substantive element of our NVivo analysis aimed to categorise values that smart grid investments confer on the municipal scale. For the purposes of this analysis we class the municipal scale as that which comprises both local authorities and their wider economic development territories such as those described by Local Enterprise Partnership (LEP) areas.

3. Results and discussion: values in the smart grid

This section is constructed in three parts. Firstly, we describe how value is traditionally measured and captured in smart grid investments. Secondly, economic values arising from smart grid investments at the municipal scale are analysed. Finally, we describe how new value capture opportunities can reduce the financial risks of smart grid deployment.

3.1. Traditional value in the smart grid

The initial regulation of the privatised UK energy distribution system relied on price incentives to drive efficiency, maintenance and asset renewal. The "RPI-X" formula was the mechanism used under the distribution price control reviews (DPCRs) to set allowable revenues for the seven Distribution Network Operators (DNOs). The DPCRs ran for five years each, with the DPCR 5 period, covering 2010–2015, the last to use "RPI-X" mechanism (Ofgem, 2010b). "RPI-X" caps price increases to the distribution use of system charge (DUoS), the predominant revenue stream of DNO's levied on consumer bills. The DUoS charge cap is based on the rate of inflation defined by the Retail Prices Index minus a factor "X" (hence, "RPI –X"). "X" is a function of the capital and operational expenditure (CAPEX and OPEX respectively) of the DNO. For the OPEX element, DNO's are incentivised by benchmarking against the best practice DNOs in the sector. For CAPEX, the assessed value of the asset base, plus investment, minus depreciation equals the asset value. DNOs earn an allowed rate of return on these assets based a weighted average cost of capital (WACC). Together with separately calculated service incentives, this represents the revenue structure of the UK's regulated distribution business model. Due to new duties placed on the regulator (the Office of Gas and Electricity Markets, "Ofgem") to take account of factors other than cost, such as climate change targets, fuel poverty and security of supply (Xenias et al., 2014), the RPI-X mechanism has been described as unfit for purpose. This is based on the grounds that it incentivises incremental efficiency gains over system innovation, and so fails to deliver environmental and social benefits (Müller, 2011). In order to incentivise a "timely delivery of a sustainable energy sector" (Ofgem, 2010b, p. 4), RPI-X has been replaced by the RIIO (Revenue = Incentives + Innovation + Output) framework for the price control review currently being negotiated, which will cover the period 2015–2023 (Ofgem, 2010b; Müller, 2011). The RIIO framework is a significant shift towards an allowable revenues structure that better incentivises smart grid solutions. Space constrains a detailed assessment of the RIIO incentives (see Xenias et al., 2014; Müller, 2011; Ofgem, 2010b). What is important to our analysis is the reaction of the DNOs to RIIO, and the question as to whether the new price framework is expected to incentivise enough investment in smart grids to accommodate the volume of renewables necessary to meet decarbonisation goals. Our DNO respondents broadly understood the move to RIIO as positive for smart grid investments:

"The key game changer with RIIO is actually we get told we have to fix our problems, so we have problem areas where we can fix them traditionally but we could also fix them with innovation [smart grid technologies]. So it [RIIO] doesn't specify that you have to install so many cables, so many overhead lines so many transformers. It just tells you, you have to fix the problem. That really opens up the opportunity for us to use innovation in that way" (DNO interviewee, 2014).

RIIO allows smart grid technologies to be assessed alongside conventional reinforcement solutions, which is more in line with a commercial logic of technology deployment on a cost basis as opposed to constraining activities to those that meet regulatory standards. Whether this will be enough to incentivise sufficient grid infrastructure investment to accommodate the necessary renewable capacity to meet climate change targets was described as the *"million dollar question"* by one DNO respondent. Across the DNO sample, there was deep uncertainty as to the ability of the new framework to incentivise sufficient innovation to manage the volume of RE compatible with the UK's emissions reductions targets.

This brings smart grid investment decisions in the UK closer to what Jackson (2011) describes as the "smart grid investment problem" (Fig. 1) where the aggregated benefits of smart grid technology deployment define the likelihood of smart investments. Yet, whereas Jackson (2011) includes remote meter reading and demand side management (DSR), these are un-captured values for DNOs due to the structure of the UK energy market (see below).

*These values are illustrative only and define the problem, they do not relate to the relative value of each benefit.

The "risk" element of Fig. 1 in a UK context is notionally complicated by the strength of the regulatory incentive, yet Fig. 1 still holds as a sufficient description of the problem. Clearly, if further values exist and can be leveraged, the volume of the risk arrow will reduce. What values are there in smart-grid transitions that are not captured by the investing utilities, and which actors might be interested in appropriating them?

Bialek and Taylor (2010) describe a "broken value chain" in the smart grid. Houseman (2008) demonstrates the disaggregation of vertically integrated utilities also disaggregates the ability to capture value from specific smart grid investments. Xenias et al. (2014) describe the "value chain" in the smart grid to comprise familiar market participants who may be further enabled by smart technology deployment. Certainly it is important to begin to research business models to enable smart infrastructures from within the existing sector (see Agrell et al., 2013); here however we are concerned with the values accruing to non-traditional actors, i.e. growth coalitions/municipalities. We see the rhetoric on Localism, City Deals and the aspirations of several core cities and municipalities as recognising the ability of smart infrastructures to unlock growth opportunities.

Currently, potential smart grid values accrue to conventional and renewable generators, households, SME's, suppliers, metering companies, and the natural environment. However, these values are not included in the current cost benefit case for DNO investments, represented in Fig. 1, i.e. benefits are "mismatched" to costs due to the institutional and business model regimes in the current UK system. Whilst values accruing to individual households, business and industry may be captured by each individual, the aggregation of these values at the city-regional scale may lead to significant geographical value propositions which go unrecognised. Indeed, in an analysis of the pathways the UK might take towards the development of smarter grids, Balta-Ozkan et al. (2014), recognise a clear role for municipalities in a more distributed energy future. This is a further justification for using Jackson's (2011) framing of the smart grid investment problem, as Jackson's work was aimed at defining the smart grid investment problem for municipal utilities in the US, yet it still omitted these municipal scale values.

3.2. Alternative values in the smart grid

Cities are no strangers to speculative infrastructure spending to secure inward investment. As described in our literature review above, acting to secure inward investment by utilising infrastructural incentives is a primary activity of growth coalitions; those individuals, institutions and partnerships with a stake in local economic growth. In many cases, this leads cities to make infrastructure investments ahead of need, in order to reduce relocation costs for firms and secure mobile investment (Hildreth and Bailey, 2013). Equally, recent treatments of renewable generation values in municipalities describe the values directly accruing to the area; these are an increased tax base and employment growth (Heinbach et al., 2014). Our definition of municipal value for this analysis are those *economic* values which either represent a direct exchange value (i.e. revenues), such as increased tax bases or payments for energy services, or indirect values such as territorial employment growth. This leaves any social and environmental values uncaptured, which could be addressed by further work. Below, we analyse three economic values identified by our sample that accrue to city-regions through smart grid deployment. These categories are: (1) renewable energy connection co-ordination; (2) inward investment stimulus; and (3) municipal supplier load control.

3.3. Renewable energy connection co-ordination

Currently in the UK, network connections are offered to generation developers on a first come first served basis. If there is capacity on that part of the network to connect the generation, a connection is paid for by the developer. If there is no capacity on the network, the developer must pay for network reinforcement for the scheme to progress:

"What the process has been over the last ten fifteen years is basically we sort of sit here in a little bubble and wait for somebody

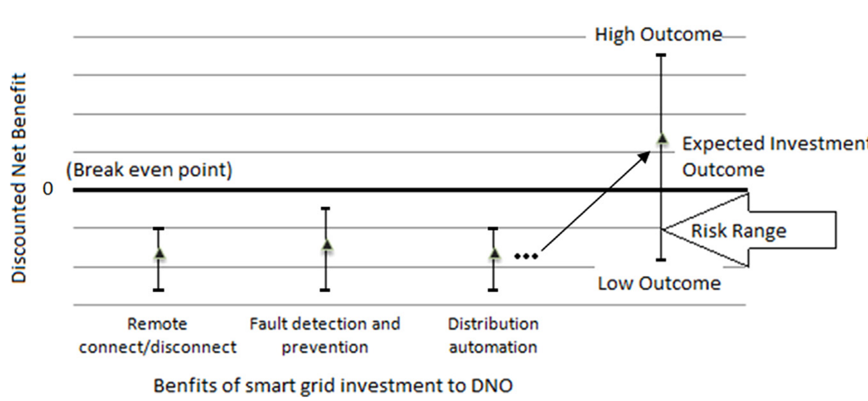

Fig. 1. The smart grid investment problem*. Source: Adapted for the UK from Jackson (2011) p.77.

to come to us and say "we would like to build a generator here". We go "yep okay it's going to cost X amount" "(DNO interviewee, 2013).

Our DNO stakeholders identified several schemes where innovative connection agreements, which avoid or postpone grid reinforcement, are being offered through the innovation funding incentives already available (e.g., SPEN, 2013; SSE, 2012). They also cited the RIIO framework as further incentivising innovative connection agreements to bring more renewables onto the network without resorting to traditional reinforcement (see Anaya and Pollitt, 2013). What has been absent thus far has been a co-ordinated approach where proximate developers looking to deploy generation capacity in similar timeframes have been aggregated to facilitate expanded use of these new connection business models:

"…if somebody was taking the lead on co-ordination, because often what we find is if there's three organisations looking to connect to the same part of a network and if they all got together there would be a sensible and economic solution that met all their requirements, but trying to get those three parties to work together…." (DNO Interviewee, 2013).

If a municipality were to co-ordinate the points at which new generation developers contact the DNO, more innovative connection agreements could be offered and thus an area may attract more developers. As Heinbach et al. (2014) show, increased tax bases and employment benefits can accrue to municipalities arising from renewable developers (also Busch and McCormick, 2014). Our municipal interviewees saw the value of increased local renewable generation schemes to municipalities, and described actors in a growth coalition (the LEP in this case), as being active in seeking them:

"So to date local authorities, the way they thought about renewable energy has tended to be, it's been about as a regulator, they have come at it very much from a planning side of things [...] Since the LEP's come along there has been a lot more momentum to sort of act more like a project sponsor I suppose, to start finding opportunities for renewable energy and be a lot more bullish about getting funding for those and getting investment in" (Local growth actor Interview, 2012).

The same respondent referred to developing a "pipeline" of renewable energy schemes in the area to enable further inward investment. There is an identifiable value for municipalities to manage "tranches" of generators utilising their resources in spatial planning to co-ordinate developer connections. This would increase the attractiveness of the city-region/territory for RE developers due to lower grid connection costs and thus capture the tax and employment values RE can bring to the municipal area. Though one should note the business rates from RE schemes would currently be nationally pooled, the announcement from the UK Government that rates from hydraulic fracturing (fracking) operations may be retained by municipalities, demonstrates the feasibility of allowing energy scheme rates to be retained at the local level (Sandford, 2014).

The first new value stream identified by this analysis is the enhanced investment in local renewable energy schemes in these areas, and the tax and employment benefits directly generated by those installations. These benefits are enabled by new connection business models, which allow DNOs to connect more RE schemes in a given territory without expensive traditional reinforcement. Due to regulatory constraints on DNOs, it is commercially difficult for them to co-ordinate or "aggregate" RE developer connections. Municipal actors, on the other hand, can perform this role and thus capture the benefits of expanded generation business location.

3.4. Inward investment stimulus

Whilst new RE schemes can bring direct economic benefits to municipalities, the capacity of the distribution network can constrain or enable inward investment from other sectors. The following is an extended quote from a municipal respondent that clearly describes a real world example:

"Ok this is a very simple example. Out at [local enterprise zone name] as part of the City Deal we obtained any business rates growth that we drive in there, we retain 100% of it within the city. That is a colossal area but it is absolutely constrained on the DNO network. So we have got three supply points into that area from the 132 kV step downs to the 32 kV network. Two of them are completely full up and one of them is getting very close to capacity. So that is going to be a massive constraint upon our building out in that area, or there is going to have to be some upgrade to those supply points so we can actually take on more electricity and actually build out on that area, and it is also the area where we can put the most generation on as well [...]. So we are looking at that and saying this is going to be a constraint issue for us. [...] so effectively what we want to do is we want to come in there now and say we will put a distribution network in and that might free up avoided cost of what they [Incumbent DNO] would need to do on their network. Off the back of that is there some different type of relationship where we can actually do trading between us and [DNO name] in terms of those avoided costs and actually the electricity across the networks" (Local growth actor interview, 2014).

In this case, a local growth actor recognised the constraint on the DNO network can be alleviated by municipal investment in smart grid solutions. Other municipal respondents were equally aware of the potential to use smart solutions to free up capacity in designated development zones. This leads to value stream 2: additional inward investment enabled by smart grid investments from economic development funds. Similar to value stream 1, values are captured in tax base increases and employment growth, but from investment enabled in sectors beyond energy generation.

3.5. Municipal supply and demand response

The two value streams above are on the "supply side" of benefits of the smart grid. On the demand side, reducing consumer loads can also facilitate increased investment and renewables connection through load control (not to mention aggregated household savings). DNO stakeholders described why the UK's smart meter roll out being delivered by energy suppliers (HM Government 2013a) means the DNOs will not have direct access to demand side response (DSR), i.e. real-time management of electricity demand. This disables a key smart grid benefit (Jackson, 2011). There are three reasons smart meters rolled out by energy suppliers (the company to whom customers pay the bill) disables DSR in the UK. Firstly, as energy suppliers do not own distribution networks, the company receiving meter data has no link to DNOs. Secondly, suppliers operate nationally and have no geographic focus, customers in a given area receive the meters ad hoc; this means only a small percentage of households or businesses would be reachable by tariff based load constraint:

We have no access to load control via smart meters. [..] given that we probably won't have majority penetration of smart meters into GB until probably 2018–2019, using DSR in anger is probably a few years away" (DNO Interviewee, 2014).

Thirdly, our DNO sample did not see the large, incumbent suppliers as being interested in partnership business models to operate DSR, which is partially based on the second point of geographic mismatch between national supplier and localised load constraints.

If, however, a municipal scale, geographically focussed supplier held substantive percentages of demand in an area, and had access to load control themselves (being the supplier they would own the smart meter), DNO's would be able to contract with this local load management and deliver the demand side benefits of smart grid deployment:

"…there would be nothing stopping a group of houses or a group of businesses all signing up to the same supplier [...] and the supplier coming to us and saying right, rather than adding another transformer how about we offer you demand side reduction and we would be interested in taking that off them so we wouldn't have to do reinforcement" (DNO interviewee, 2014).

Indeed, one DNO had already investigated the option of directly contracting commercial customers for load control but also described the benefits of aggregated business models based on geographically defined supply contracts:

"We have also explored the model of us directly engaging and signing up customers and also working with aggregators who will also sign up customers, and we engage with an aggregator [...] At the moment there isn't any organisation that we are aware of that has thousands of customers aggregated in one geographic area."

Interviewer. "Which there would be is there was a city scale energy supplier?"

"Absolutely yes but at the moment it's not currently there to be trialled" (DNO interviewee, 2014).

However, the Core Cities group has stated the intention of its eight constituent municipalities to set up energy supply companies by 2020 (Core Cities, 2013). A local authority officer respondent close to this process signalled the intention to go *"smart from the start"*, installing smart meters for each new customer from the beginning of the programme. The inherent close geographical focus of a municipal supplier, means the problems of supply tariffs being owned by large national utilities who may be unwilling or unable to engage at neighbourhood level with DNOs, would eliminated by a municipal supplier business model. As such, demand side response contracts could be negotiated with municipal suppliers. Once customer connection in a given area are high enough, DNOs would be willing to pay for demand side response. This leads to value stream 3, automated demand side response (DSR), which is a traditional component of smart grid cost benefit analysis that is disabled in the UK by the political and institutional choices associated with the smart meter roll out. As we have shown, this can be overcome to some extent with municipal scale supply contracts.

3.6. Smart grids as smart urban infrastructure investments

The above analysis has identified three smart grid enabled economic value streams that accrue to municipal actors that have hitherto been unrecognised in the UK's smart grid investment calculus. Mechanisms for value capture here are already being explored. Business rate retention in enterprise zones in particular represents a demonstrable fiscal value stream which accrues to host municipalities. Investing in infrastructure ahead of these values is a recognised feature of economic development activity. Recently, Greater Manchester has agreed a "revolving infrastructure fund" with £150 m retained business rate revenues (GMCA, 2012). Sheffield, Newcastle and Gateshead, and Nottingham have secured powers to raise a combined total of £133 m for speculative infrastructure investment to secure growth (Sandford, 2013). Much of these revenues are often directed towards transport investment as transport networks are the responsibility of the municipalities, whilst energy networks are not. Our research suggests that there is no functional reason why municipal infrastructure funds cannot be deployed for smart grid infrastructure.

Whilst rate retention is a direct economic value stream, the employment benefits identified in the smart grid are indirect, but can equally be paid for by economic development funds. Leeds City Region, for example, is aiming to raise almost £1.5bn over the next ten years to fund transport and economic infrastructure with no prospect of recouping the cost directly. This is because the promoters of the new transport fund, which forms a cogent growth coalition in Leeds, believe the combined schemes will lead to 20,000+jobs in their geographic area (LCRP, 2013).

The volume of capital that growth coalitions are willing to deploy to secure infrastructure aimed at facilitating growth is substantial. This research has characterised just three clear municipal economic values not currently captured in the RIIO framework or in the smart grid investment literature. Supply side constraints on multiplying RE generators and stimulating inward investment can be reduced by using economic development funds to pay for developer co-ordination and stimulus monies can be channelled to "hard" technology investments in partnership with DNOs. On the demand side, municipal energy supply companies deploying smart meters would enable meaningful demand response contracts to be negotiated with DNOs, both realising the technical benefits of load control and strengthening the economic case for municipal supply companies. This may also facilitate value streams 1 and 2 as demand side response may further release capacity on the network for RE schemes or for land use intensification. We can thus amend the smart grid investment problem (Fig. 1) by paying attention to these values, and the business models and institutional structures that might capture them in Fig. 2.

*These values are illustrative only and define the problem, they do not relate to the relative value of each benefit.

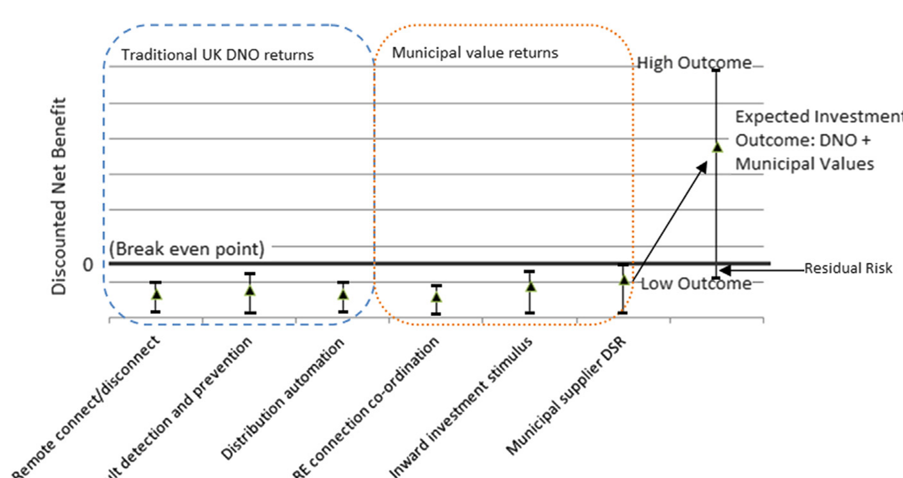

Fig. 2. The smart grid investment problem taking account of municipal economic value returns*.

By including these municipal value streams in the smart grid investment problem, risk is reduced. With a reduced risk proposition, the cost of project capital may also be lower, further enhancing the viability of a given smart investment.

3.7. The combined approach – co-evolving smart grid value capture

To capture all the benefits of these municipal values, new institutions and business models will be required. DNOs will need to demonstrate the characteristics of more active distribution *system* operators (DSOs) which utilise smart grid investments to operate an active power system (Openshaw, 2012):

"I think that's kind of part of the **evolution** to us becoming a DSO, is to be able to engage in those sort of relationships [...] It's not the technology and the smart grid stuff because that's… I refrain from saying easy but that's sort of a known quantity, we know how to do that, it's the business models and the contractual relationships between people that throw up the shaky ground I think" (DNO Interviewee, 2014, our emphasis).

One particular enabling business model for each of the values identified above would be a municipal (i.e. city scale) supply company. This could take the form of a traditional supply company or may adopt an ESCo model (Hannon et al., 2013). A municipal supply company can further aggregate RE developers by offering attractive power purchase agreements (PPAs) to RE developers *and* it can achieve the aforementioned geographic DSR. By combining the benefits of a municipal supplier at the city scale, a strong case for economic development funds to be applied to smart grid infrastructure can be made. Indeed this combined structure is the very aspiration of one of our local growth actors in the municipal energy space:

"…what we are looking to do here in [city name] is to use our purchasing power to enter into PPA agreements with community groups who want to install small scale generation, turbines, tidal, wind, stuff like that. We would be able to do some deals with our energy from waste plant, we would be able to get into that whole area where we can sort of drive sustainable and local low carbon energy zones to drive economic growth in that area" (Local growth actor interview, 2014).

Combining the municipal values in the smart grid under municipal energy supplier business model is, we argue, one way to accelerate smart grid investments. Growth regimes in various cities have assembled substantial infrastructure funds, economic partnership institutions and value capture mechanisms that could be applied to smart grid investments. Their increasing interest in energy infrastructure makes this analysis timely, as characterising these fiscal and economic values is the first step toward quantitative evaluations.

4. Conclusions and policy implications

There are clear policy implications from this research. Firstly, to capture RE developer co-ordination values, the economic development strategies of municipalities should begin to treat electricity grids as enablers of economic growth just as they do transport and communications infrastructures. As a first step, local authorities should collate the planning applications within the development control process and invite expressions of interest from proximate developers for a non-firm (interruptible) connections offer to be extended to their incumbent DNO. Secondly, as has already been intimated by Core Cities (2013), a more structured role for municipalities within DNO network planning is needed. This would mean better co-ordination of the economic plans of Local Enterprise Partnerships and the spatial plans of Local Authorities, with the knowledge of geographic network constraints at DNO level. The opportunity for local authorities to capture business rate uplifts from renewable generators should be extended in the same way as proposals for fracking sites have been. This would ensure municipalities capture value from, as well bear the impacts of, renewable energy developments. To capture the values of inward investment stimulus, the economic development funds being assembled by LEPs, and their associated value capture models of Tax Increment Finance and "Earnback" (Sandford, 2013), should be extended in scope to incorporate smart grid investments. Most of these new funds have an overwhelming transport infrastructure focus (by capital value), and should be encouraged by national actors such as Ofgem and DECC to search for other infrastructural opportunities, such as releasing growth capacities on constrained sites by smart grid interventions. Together with the new pricing framework under RIIO, this would be a substantial boost to the volume of capital available for smart innovation. Finally, the ability to capture values from demand response, enabled by the municipal supplier business models, needs further development. This suggests that municipal supplier companies could bring back demand side response as a value in the smart grid investment problem for the UK. The first step towards realising this would be for the RIIO innovation funds and LEP economic development funds to search for candidate sites where this latent business model can be applied. However, this business model raises fundamental challenges for the current UK political and institutional model of competitive markets for energy supply, which are based on customers being able to switch suppliers to reduce the unit price of their electricity supply. To be commercially viable, a municipal supply company would need to have a secure customer base within the region.

This analysis has shown that, by combining the insights from socio-technical transitions and urban political economy framings, it is possible to demonstrate how values in the smart grid can be captured by urban growth interests using new business models at the municipal scale. The increasing focus on infrastructural enablers of growth at the local level is permeating into the economic strategies of urban governance. For the UK energy system, growth coalitions (formalised in LEPs) are becoming a more significant part of the institutional system, as they begin to focus on the benefits smart technologies can bring. It follows that the technological and institutional elements of the system are co-evolving with new actors in the institutional space, as described Foxon's (2011) co-evolutionary framework. Smart grid technologies facilitate new ways of thinking about the values of urban infrastructure; driving a search for new business models. The role of urban space, and how the governance of that space interacts with infrastructure systems, is critical to understanding the types of agency in different infrastructural contexts.

This analysis has highlighted three additional economic values that accrue to city-regions through smart grid deployment: (1) renewable energy connections co-ordination; (2) inward investment stimulus; and (3) municipal supplier load control. This is not a comprehensive list, which would need to incorporate social or environmental values of smart grid investment, and describe the wider values of municipal participation in energy services. However, that by analysing stakeholder values from the currently separate communities of DNOs/Regulators and municipalities/growth coalitions, we have identified value propositions that have hitherto gone unrecognised in the UK's version of the smart grid investment problem.

Further work will investigate the creation of relevant business models in an empirical setting. Following the insights above, future research will use case approaches to undertake quantitative analysis of these economic values, and also social and environmental and wider values. There is also a need for further international treatments of energy system transitions, where urban political economy and energy systems have co-evolved differently and may highlight further value streams which may be captured by novel systems perspectives.

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