Smart grid-lock? The role of ideas, interests and institutions in contestations over the future of electricity networks in Britain[1]

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1. Introduction

An essential element in a future UK low-carbon energy system will be electricity infrastructure that can facilitate more flexible demand, the balancing of variable renewable generation, and the incorporation of local small-scale technologies such as solar PV, and new technologies such as electric vehicles (e.g. ENSG 2009, DECC 2009, Cary 2010). Such 'smart' grid infrastructure will need to incorporate greater observation, control, and automation, through incorporation of information and communication technologies, and integration with new low carbon generation and en energy end use technologies (DECC 2009: 14). The need for transformation is generally greatest on low-voltage distribution networks.

The smart grid agenda involves not only technological innovation, but also innovation in business models, network operation and social practices. It is widely recognised that it will also need major changes in policy and regulatory frameworks, particularly because the entities currently responsible for distribution network operation and investment in the UK are regulated monopoly private companies, whose actions are largely determined by those frameworks. This arrangement means that the creation of spaces for innovation protected from normal commercial pressures (Kemp et al 1998) takes a different form from that in competitive markets, and is more heavily dependent on policy than usual. However, the exact nature, scale and speed of policy and regulatory change needed for a smart grid in the UK has been heavily contested over the last decade.

The first aim of this paper is to give an account of that history. A second aim is to assess how far the evolution of policy and regulation so far is likely to be in fostering smart grid investment and operation. In doing this, I draw on an approach developed by Kern (2012), who uses the multi-level perspective (MLP) on socio-technical transitions as a framework, and in particular how far policy interventions create 'niches' for innovation and destabilise existing 'regimes' of operation and investment in energy systems. I argue that, assessed in this way, policy and regulatory change to date has only partially supported innovation in smart grids, mainly because it has not provided sufficient destabilisation of the existing regime in network investment and operation. An exploration of why this has been the case is the third aim of the paper. Here I draw on new institutionalist approaches in political science to understand the interplay between the ideas, institutions and interests that surround the immediate debates on policy for smart grids.

There has been increasing interest in recent years in smart grids from economics (Pollitt and Bialek 2008), innovation studies (e.g. Bolton and Foxon 2010) and energy policy studies

(Woodman and Baker 2008, Shaw et al 2010) as well as think-tanks (Cary 2010), which this paper builds on. However, while these analyses all touch on aspects of changes in regulatory and policy frameworks that are political in nature, they are principally concerned with policy analysis and recommendations, and do not take an overtly political perspective on the intended shift towards a smart electricity grid (an exception is Mitchell 2008). By contrast, here my focus is explicitly on the politics of innovation policy. These studies also all pre-dated important recent developments in electricity network regulation, notably the completion of a major review of the regulatory regime in 2010 (RPI-X@20) and the launch of a new regime subsequently.

The paper is structured as follows. In the next section, the ‘smart grids’ concept is briefly explained, along with why it is important for a more sustainable electricity system. Section 3 gives a brief account of the evolution of the framework for electricity distribution network regulation. In section 4 I turn to some of the key areas of contestation in the smart grids agenda. Section 5 then applies the MLP framework to the question of how far current policy and regulation can be expected to lead to innovation. The picture which emerges is one in which major political pressure has led to increased support for smart grid experiments, but not radical change in the regulatory, technological and commercial regime. The reasons for this continuity, are explored in section 6, drawing on institutionalist approaches. Section 7 concludes.

2. The smart grid agenda in a low carbon energy system

The concept of a ‘smart grid’ has emerged in recent years as a core element of a more sustainable electricity system. There is no single agreed definition of a smart grid, but the basic principle is the application of information and communication technologies (ICTs) to electricity networks to allow: greater observation of the state of wires and other assets; control of power flows; automation of management of power fluctuations of outages, and integration of new low carbon generation and demand side technologies, such as solar PV, heat pumps and electric vehicles (DECC 2009: 14).

The smart grid agenda applies largely to the low voltage distribution networks, as the high voltage transmission system is already ‘smart’ to some degree. Existing electricity distribution infrastructure has been developed to serve predictable and regular patterns of demand and generation (Shaw et al 2010: 5927). Almost all electricity generation has been centralised in large power stations, with a one-way passive network sending power from those power plants to consumers. If electricity generation and use is to become more sustainable, networks will have to be transformed in the way that they work.

First, a low carbon electricity system will need a much higher proportion of renewable generation. A significant proportion of renewable capacity, including onshore wind and solar PV, is likely to connect directly to distribution networks. These have been designed purely to push power to households, businesses and industry rather than to *absorb* power from sources such as wind turbines and solar photo-voltaic (PV) panels (Ochoa et al 2010). A second issue is the balancing of the system. Electricity systems have to maintain a constant balance between demand and supply in real time to avoid blackouts. Currently this is achieved by matching supply to regular patterns of demand for electricity (peaking in the morning and early evening), with power stations being deployed or withdrawn over the course of the day (and indeed over the year). However, renewable electricity technologies produce varying output of power with changing patterns of wind and sun etc. Low carbon electricity systems will therefore have to vary demand to match supply, along with a greater role for electricity storage. Smart meters will play a crucial role in this process, along with a new role for consumers, either consciously responding to price signals or allowing automation of such response.

A third issue is the anticipated electrification of both heating and transport. In a low carbon future, the Government anticipates that a significant proportion of heating will come from low carbon electricity using heat pump technologies (DECC 2013). At the same time, internal combustion engines are likely to be replaced by batteries in electric vehicles. Both these developments will add considerably to the demand on the electricity system, increasing the value of more efficiency in network design and use (The Climate Group 2008). However, they also potentially provide very useful new ways of balancing the electricity system, because they effectively introduce distributed forms of mass energy storage on the demand side (e.g. Strbac et al 2010).[2] This means that grids must be able to communicate with heat pumps, electric vehicles and appliances, through smart meters. Network operators will want to be able to observe how much power is flowing where, in real-time. They will want to be able to manage and optimise demand as far as possible, effectively evolving from network operators to local electricity *system* operators. It will also be helpful to automate much of this process (Northcote-Green and Wilson 2006). This vision contrasts sharply with the grid that the UK has at present. Parts of the distribution network date back to the early part of the last century, and levels of system observability are very poor. Building a smart grid is therefore a major undertaking.

3. The evolving framework for electricity distribution network regulation in the UK

It is widely argued that the transformation of distribution networks will require also major changes in the *governance* of the bodies that invest in and operate those networks. Since 1998, networks have been run by private companies known as distribution network operators (DNOs) (Helm 2003: 258). There are currently 14 DNOs in the UK, each of which distributes electricity to all consumers in their geographical area. While generation and supply (retail) of electricity have been liberalised, networks remain regulated as natural monopolies. Thus the key locus for smart grids policy in the UK lies in electricity regulation, which since 2000 has been located in the Office of Gas and Electricity Markets Authority (Ofgem).

The approach to regulation of electricity networks up until very recently was originally set at privatisation in the late 1980s, and is known as 'RPI-X'.[3] Electricity supply companies pay a charge to the DNOs for the use of the network, which is passed on to consumers. The amount that can be charged, and hence the revenue of the DNO, is set by the regulator for a certain period (up until 2015 these have been 5 year periods known as 'distribution price control reviews' or DPCRs). Ofgem also agrees a capital investment programme with the DNOs for the period. Each company's overall revenue allowance is then adjusted firstly to take account of inflation (i.e. the RPI) and secondly by a factor 'X', which is intended to induce efficiency gains.[4] A number of additional incentive schemes related to the performance of the DNO, for example in avoiding blackouts and providing connections within a certain time period, are also then applied. Any savings that the company can make within this revenue envelope can be retained by the company as profit, and distributed to shareholders.

Most observers argue that the RPI-X regime increased efficiency, especially on the operating side, but has not incentivised long-term technological innovation or innovation in business models. For example, one senior Ofgem figure argued in 2010 that: "It would be crude but not an unrealistic simplification to say that the way energy networks are designed, built and operated has not changed significantly since they were built in the post war period." (Smith 2010: 9). Given this background, it is not surprising that changes in regulation that would encourage low-carbon innovation have been slow. The need for such innovation has been on the agenda at least since the beginning of the 2000s. At a high level, successive governments throughout the decade have made several changes to the remit of Ofgem through legislation or guidance in an attempt to get climate change and the need for low-carbon innovation in networks higher on Ofgem's agenda, amongst other issues (Cary 2010, Shaw 2010, DECC 2011a).

Early in the decade, the wider smart grids concept was not yet on the agenda, and the main focus of debate about low-carbon innovation was the connection of *distributed generation* (including wind, combined heat and power, and increasingly, solar PV) to distribution networks (Woodman and Baker 2007; Pollitt and Bialek 2008; Shaw et al 2010). High connection charges, where potential generators were charged the full cost of any necessary reinforcements across all voltage levels of the network were seen as inhibiting investments, while at the same time, generators were not receiving any reward for the benefits they offered networks in terms of reducing peak flows of centrally generated power. Following lobbying by generators, a series of working groups were set up from the late 1990s and proposed a number of changes. These included partially socialised, "shallower" connection charges for individual distributed generators, the wider sharing of distributed generation (DG) benefits with customers, changes to engineering standards and a specific DG connection incentive for DNOs being introduced from 2005 onward.

However, distributed generation grew far less than expected over this period. The DG incentive was seen as ineffective (Woodman and Baker 2008: 4529-30), partly because it was more than offset by other incentives, including the loss of revenue from distributing centrally generated electricity (Shaw et al 2007: 4). By 2012, Ofgem was admitting that it had had little effect (Ofgem 2012). More fundamentally, DNOs did not see connecting and managing DG as part of their core business, and tended to want to deal with projects on a piecemeal basis (Mitchell 2008: 153; Bolton and Foxon 2010: 16, Cary 2010: 68).

Another key area was *research and development* (R&D) on networks. As noted above, the regulatory regime gave no incentive to companies to innovate, and by 2004, UK network companies were spending less than 0.1% of revenue on RD&D (Pollitt and Bialek 2008). In DPCR4 (2005-2010), Ofgem introduced two sources of dedicated funding for experiments in technological and commercial innovation, especially aimed at ways of handling variable distributed generation in new and more cost-effective ways. One was the Innovation Funding Incentive (IFI), allowing DNOs to claw back costs of R&D up to 0.5% of revenue. The IFI increased R&D spending by DNOs from around £2 million in 2003/04 to around £12 million in 2008 (Jamasb and Pollitt 2011: 313), and was seen as relatively successful, although still small-scale. The second was Registered Power Zones - a scheme aimed at demonstrating innovative solutions to the connection of new distributed generation on a larger scale (Mitchell 2008: 153). However, only a handful of schemes materialised in the price control period, which was seen as symptomatic of the failure of RPI-X regulation to provide incentives for innovation (Woodman and Baker 2008: 4529; Bolton and Foxon 2010: 17; Mitchell 2008: 154).

However, these schemes remained quite isolated from mainstream investment and operational decisions, with no incentive for DNOs to apply them under RPI-X, which has encouraged capital-intensive ‘fit-and-forget’ network reinforcement rather than more flexible approaches (Shaw et al 2010, Smith 2010, Jamasb and Pollit 2007). Writing in 2008, Mitchell argued that “although this issue [i.e. low carbon innovation] has been looked at in detail since 2000, there has been very little *actual* change in the design and operation of the networks” (2008: 149) because the nature of regulatory incentives had not changed. Mitchell (2008: 153) also makes the point that any measures introduced to incentivise innovation (such as the IFI and RPZs) still had to be justified in terms of net benefits to customers, showing how Ofgem’s core focus on efficiency remained dominant throughout the decade. In Mitchell’s terms, the regulator remained on the wrong side of the “innovation fault-line”: over-committed to market-mimicking mechanisms; not willing to channel and direct innovation; over-committed to the least-cost option over the environmental option, and seeing innovation as a technology-only issue rather than a ‘system’ issue (Mitchell 2008: 12-13).

Based on this experience, there were calls to increase the scale of funding (Pollitt and Bialek 2008), to allow more collaboration across the value chain, with consumers, suppliers and ICT companies (Cary 2010) and to do more to ensure that technical innovations developed under funding mechanisms were mainstreamed into investment programmes (Bolton and Foxon 2010). In DPCR5 (2010-2015), a new Low Carbon Network Fund (LCNF) was set up, which allowed DNOs to bid for up to £500 million over 5 years (Ofgem 2010), an order of magnitude larger than the IFI, as well as being significantly bigger than comparative schemes in other countries. This scheme allowed DNOs to cooperate with suppliers, generators and consumers in projects, and also required findings from projects to be shared publicly.[5] This much larger resource for experimentation appears to have resulted from intervention from a senior Ofgem staff member with engineering experience, rather than from the institutionally more dominant economists. This staff member has since left the regulator and their post abolished.[6]

By the late 2000s, criticism of Ofgem’s lack of action on low-carbon innovation was increasing, including a report by the Sustainable Development Commission (2007). Partly in response to these debates and pressure from the government, Ofgem started to undertake a number of strategic reviews of the electricity system and its regulatory frameworks in the latter part the decade. In 2006, Ofgem set up a project looking at long-term future scenarios for electricity networks (Ofgem 2008). However, this remained a scenario exercise, with no direct connection to actual regulation. More importantly, in late 2008 what Ofgem called a ‘root and branch review’ of the overall regulatory framework for networks was started, called ‘RPI-X@20’ because RPI-X regulation had been in place for around 20 years (Ofgem 2009). RPI-X@20 was motivated partly by the low-carbon energy agenda, but also by a set of issues to do with greater consumer engagement and the idea of regulating for outputs rather than simply cost. RPI-X@20 led directly to what Ofgem have presented as a new regulatory model for networks, called ‘RIIO’, standing for ‘Regulation = Incentives + Innovation + Outputs’ (Ofgem 2013). RIIO applies across both gas and electricity, and to transmission and distribution. The new price control review under the RIIO approach will be known as RIIO-ED1 and will run from 2015 to 2023.

The RIIO-ED1 framework will drop the DG incentive, seen as too complex and ineffective. Instead, Ofgem decided that DG should be treated within the general framework of incentives for good connection and other services that covers demand users (Ofgem 2013b: 26).[7] Ofgem argues that DNOs will be incentivised to keep reinforcement costs as low as possible through the incentive to make low investment bids. In RIIO-ED1 this applies to 100% of total

expenditure, in principle allowing DNOs to treat all expenditure the same and to find smart solutions (*ibid*: 29).
The new framework also replaces the LCNF with an "innovation stimulus" (Ofgem 2103b: 97). This consists of a Network Innovation Competition (NIC), in which companies bid for funds for large scale projects, similarly to the LCNF, and a use-it-or-lose-it Network Innovation Allowance (NIA) for smaller projects, of up to between 0.5 and 1 % of revenues. The NIC is resourced at around £90 million a year for the first two years of ED1, i.e. a slightly lower level than the LCNF. In addition, RIIO-ED1 contains an Innovation Roll-out Mechanism to fund the roll-out of proven low carbon innovations. Finally, to receive a fast assessment of their investment plans, DNOs must set out an innovation strategy in their business plans, which should include evidence of how they will incorporate learning from LCNF and other innovation trials into business-as-usual.

4. Areas of contestation in smart grids policy

By the end of the decade, wider interest in the smart grids agenda was increasing sharply. Previously, the importance of a wider transformation electricity networks for the decarbonisation agenda had been grasped in academia (e.g. Awerbuch 2004) but not widely in the policy sphere. However, by the late 2000s, partly because what were labelled smart grid investments appeared within fiscal stimulus packages in the USA and China, this began to change. In 2009, an energy distribution industry group, the Electricity Networks Strategy Group, produced a high-level plan and an attempt at a cost-benefit analysis for smart grids in the UK (ENSG 2010a) along with a 'route map' (ENSG 2010b). Meanwhile the government produced its own vision statement for the smart grids (DECC 2010). The Energy and Climate Change Select Committee also held an inquiry into future electricity networks (ECC Select Committee 2010).

Shortly after these reports were produced, DECC and Ofgem established a Smart Grids Forum, with representatives from the DNOs and some independents. The Forum has produced a number of reports on various issues, including a more complete framework for evaluating the costs and benefit of smart grids, scenarios for the uptake of low carbon technologies at regional level (EA Technology 2012), a detailed description of expected functionalities of a smart grid by 2020 and 2030 Smart Grid Forum (2011), and an assessment of regulatory and commercial barriers to the smart grid (Smart Grid Forum 2012). The work of the SGF has also led to other developments, such as reform of the main engineering rule that had been identified as a potential barrier to demand side response (Kay 2012). At the same time, the ICT industry, which has a commercial interest in the smart grids agenda, has set up an organisation called Smart Grid GB, which has also produced a social cost-benefit analysis (Smart Grid GB/Ernst and Young 2012).

However, there was far from consensus on how the policy framework for smart grids should develop. First, it proved difficult to produce agreement on the ***balance of costs and benefits*** arising from the smart grid approach. Transformation of networks to smart operation will involve considerable cost. In the UK the roll-out of smart meters alone is projected to cost £12 billion, with other system elements potentially costing in the region of £10 billion (ENSG 2009: 20-22). However, as Cary (2010) notes, there is also an opportunity, since the existing distribution network is ageing fast, and need to be replaced in any case. Many assets (wires, transformers, switching equipment etc.) are over 40 years old, dating back to a major wave of investment during the nationalised period in the 1960s (e.g. Pollitt and Bialek 2008 Figure 1; Bolton and Foxon 2010: 15) and even by the late 2000s an estimated 70% were reaching the end of their design lives (Mitchell 2008: 150). Investment needs have already risen sharply. In addition, the switching large parts of heat and transport to electricity will potentially mean even larger costs if business-as-usual approaches to network operation and electricity demand are taken.

Most assessments of a smart approach agree on that it is likely to produce a net positive benefit, relative to business-as-usual. However, with considerable uncertainty about what technologies a smart grid would incorporate, about potentially unknown benefits, with long-time scales both of investment and outcomes, and with consequently widely differing assumptions underlying cost-benefit analyses (CBA), this should not be surprising. Even in the case of smart meters, where the timeframe, nature of investment and potential benefits were much more clearly defined, CBAs results varied considerably (Mott Macdonald 2008, DECC 2013b, ECC Select Committee 2013)

In late 2009, the network industry Energy Network Strategy Group commissioned an 'indicative' CBA in collaboration with the government and Ofgem (ENSG 2010a: 16-22). This exercise produced a range of net present values for a set of smart grid investments for the periods 2010 to 2020 and 2020 to 2050 based on different assumptions about the value of benefits from those investments. The base case for 2010 to 2020 produced an NPV of £1 billion, but the low case gave a negative net value. Longer term returns were evaluated more positively, with an NPV of £2.7 billion for the 2020 to 2050 period.

Another early CBA exercise by Imperial College looked at the value of smart approaches to handling growth in heat pumps and electric vehicles through demand response and peak lopping, reducing need for investment in reinforcement (Strbac et al 2010). This produced a NPV of a smart grid strategy, relative to a business as usual strategy, of between £0.5 billion and £10 billion.

Following the formation of the Smart Grids Forum in 2010, working group 3 of the Forum commissioned Frontier Economics and EA Technology to produce a more systematic assessment framework (SGF 2012b). Based on different scenarios of low-carbon technology growth (i.e. heat pumps, electric vehicles, solar PV etc.), this exercise produced gross present value benefits for smart grid investment strategies, as compared to business-as-usual approaches. In initial testing these gave relative savings of between £10 and £19 billion up to 2050, but these were subsequently revised down to £2-4 billion, based on lower expectations about the growth of heat pumps (Neuberg 2013).

Meanwhile, SmartGridGB, a group set up by the ICT industry, undertook its own CBA (SmartGridGB 2012), based in part on the SGF assessment, using the early £19 billion figure. In addition, the report attempted to quantify benefits of smart grid expenditure across the supply chain, finding that they amounted to £13 billion of gross value added to 2050 (*ibid*: 5), and much larger returns produced by the development of 'secondary' industries in low-carbon technologies, especially electric vehicles and low-carbon heat technologies.

Thus overall, the economic case for the smart grids route, defined in various ways through different CBA methodologies, and under different assumptions about low-carbon end-user and generation technology growth, can range between the overwhelmingly positive to quite small, if not marginal. This points, amongst other things, to the problem of using a tool developed for assessing discrete projects with well-specified outcomes, given fixed preferences and behaviour, to a system transformation. To this extent, it shows the difficulty that an essentially marginalist intellectual framework (i.e. neo-classical economics) has with such transformation (see discussion below).

A second area is how ***uncertainty about future network needs and operation*** is to be handled. By the late 2000s, a number of visions of a future electricity system in the UK had been put forward, and there was a great deal of uncertainty both about technical and commercial details and about which pathways would be followed, posing the problem of how to regulate for such uncertainty (Pollit and Bialek 2008: 12). The regulatory framework of the 2000s was based on an approach that required proposed investment in networks to demonstrate need before it could be deemed 'efficient', and thus acceptable to the regulator. As a result, 'anticipatory investment' for the *potential* future use of low-carbon technologies ahead of need was risky for DNOs (Shaw 2012: 5932; Cary 2010: 79).

One response to the problem of uncertainty is to allow evolution by experiment and deeper engagement with network users to understand potential future uses (e.g. Pollitt and Bialek 2008). The other is to move in the opposite direction towards a greater degree of strategic coordination, as many independent observers and the ICT industry called for (Smart Grid GB/Ernst and Young 2010, ENA 2009b, Skillings 2010, IET 2009, Sansom 2010). This latter view rests on several arguments: to ensure common standards and interoperability (Shaw et al 2012: 5932); to overcome the problem that some of the benefits of the smart grid will fall to actors who are different from those who have to make investments (Bolton and Foxon 2010: 20),[8] and to bring together a number of potentially disparate elements in compatible ways to realise the full benefits of smart grids.[9] For example, by the late 2000s it was clear that a lack of coordination between the smart grids agenda and the design and roll out of smart meters, which was being led by suppliers, risked missing crucial potential benefits for reducing network investment requirements through peak demand reduction. Both those against and for coordination argue that their approach would avoid overinvestment and stranded assets. As Smart Grid GB (2010:) note, greater coordination would require anticipatory investment, and a major change to Ofgem's approach of "wait for proven need and provide optimal solution".[10] Shaw et al (2010) call for scenario based planning.

The RPI-X@20 review took an important step by explicitly engaging with the debate on uncertainty and coordination, posing the question in consultation documents as to whether a 'guiding mind' was needed to provide "clear guidance on what should be done to facilitate delivery of security of supply, environmental and fuel poverty targets." (Ofgem 2009a: 39). Ofgem (2009b) laid out three options: a 'central government led' model, a 'joint industry led' model, and an 'adapted regulatory framework' model. While a central government led model was acknowledged to potentially speed up change in networks, it was rejected on the grounds that it might be excessively costly and not allow enough innovation. The joint industry led model was also rejected, with Ofgem (2009b: 15) arguing that the adapted regulatory model "is potentially the most likely to ensure value for money for existing and future consumers over time". Unlike the other two models, the adapted regulatory approach was not centralised, but rather left decisions on what network companies would need to do with those companies and Ofgem, taking into account higher level Government and EU targets (Ofgem 2009b: 12). The main reason put forward for preferring this approach was that, because of the considerable uncertainty about what the efficient option for a smart grid is, any centralised approach risks imposing risks that are far more expensive than they need to be, relative to a more evolutionary and incremental approach.

Ofgem has now operationalized this approach in RIIO-ED1, by delegating to DNOs the task of forming 'best views' about the growth of low carbon technologies (e.g. heat pumps, electric vehicles, solar PV, wind etc.) on their networks in their business plans, along with investment plans for accommodating these technologies, and a smart grid development plan, as noted above. This acknowledgement of the need to plan for the growth of low carbon technologies on the basis of scenarios is the closest that Ofgem has come to approving strategic, or anticipatory, investment, although it falls short of the kind of more strategic coordination that many critics were calling for.

A third issue, relevant to the longer term than immediately, is a ***potential tension between the different uses of demand side response (DSR) for different actors***, in particular between what DNOs would gain from managing demand on networks and what suppliers, and indeed the system operator, National Grid SO, would be interested in (e.g. Macloed 2013). For distribution networks, the benefits of DSR enabled by smart grids and smart metering lie in 'peak lopping', i.e. moving part of peak demand to times earlier or later in the day, providing a smoother load profile and avoiding the need for larger networks. By contrast, the 'Big 6' suppliers in the UK, who are also vertically integrated owners of generation assets, including increasing amounts of wind capacity, will be primarily interested in using DSR to balance variable generation, as will the system operator. A key issue is then what institutions, controlled by whom and with access by whom, will be used to manage DSR. At present, DNOs have no direct relationship with domestic customers, and there is some concern that they will not be able to enter into DSR contracts which benefit them, especially relative to the suppliers (e.g. Cary 2010).

A final area is ***ownership of networks***, and the potential role of direct *competition*. British regulation had always considered networks as natural monopolies (Cowan 2006). Network companies were as a result expressly banned from owning any generation or having any supply relationships with customers, to prevent them from favouring their own business over other network users. However, this rule poses a barrier to DNOs becoming active distribution system operators (DSOs), who would actively manage and balance power flows on the network, as access to distributed generation, storage and demand side response would be needed to do this effectively (Shaw et al 2010: 5934-35; Cary 2010: 79, Bolton and Foxon 2010). At the same time, Pollitt and Bialek (2007: 18) argue that the large integrated supplier-generator energy companies that own a majority of the network businesses should be forced to divest them, on the grounds that if DNOs become more active network managers, they could effectively give priority to parent company demand side or DG contracts. More radically, and partly on the basis of innovation in telecommunications, Pollitt (2010) explored the options of introducing more direct competition, either by allowing third parties to build, own and operate new parts of networks, or even the construction of parallel networks that would give customers a choice, for example between the main grid and micro-grids. However, such ideas were strongly opposed by the networks industry body, which argued that the telecoms analogy was not applicable in the case of electricity, where a single undifferentiated service (i.e. provision of electrons) is possible (ENA 2009c)

RIIO-ED1 offers no change to the established model. In a sense, this should be expected, since allowing DNOs to own storage or generation at any scale would involve a change to licence conditions and possibly engineering codes, both of which are outside the scope of a price control review. The Smart Grid Forum has examined some of these issues (SGF 2012), but as with earlier working groups, it cannot itself make regulatory changes. Similarly, RIIO-ED1 does not touch deeper network governance issues, such as the fact that some elements, such as review of technical codes, comes close to self-governance, with distribution companies playing a dominant role.

5. How far has policy fostered innovation?

What does the history of electricity distribution network regulation laid out above imply for the potential for innovation within the socio-technical system in which those networks sit? As described above, up until the late 2000s, a major criticism of the regulatory framework was that it had failed to produce innovation. However, in the early 2010s a new regulatory framework has been introduced, which has changed some elements of the previous regime while leaving others intact. It is thus timely to re-examine the question of how far current electricity distribution network policy is likely to stimulate innovation in the direction of a smart grid.

In examining this question, I draw on a framework developed by Florian Kern (2012) that is in turn based on the multi-level perspective (MLP) on socio-technical transitions (e.g. Geels 2002, 2004, Geels and Schot 2007, Rip and Kemp 1998). The MLP sees structural change in systems happening as the result of interactions between processes at three 'levels': 'niche', 'landscape' and 'regime'. The regime, which constitutes mainstream ways of realising various social functions, provides the 'selection environment' for new technologies and other innovations (Smith et al 2010: 440). In the MLP approach, the socio-technical regime is a broad concept, incorporating not only the routines of individual engineers, and the complex engineering practices, skills, product characteristics embedded in institutions and infrastructures, but also the rules and practices of other groups, including: "users, policy makers, societal groups, suppliers, capital banks etc." Geels (2002: 1259-60). For electricity networks, within the last of these, regulation plays a particularly important role in structuring and maintaining the regime. These sets of rules and practices stabilise existing trajectories but also, importantly, blind actors to new developments outside their focus (Geels and Schot 2007: 400).

Change and innovation does occur within regimes, but is typically incremental in nature. By contrast, radical innovations of the type usually associated with socio-technical transition are generated in niches. This is where radical novelties, with an emphasis on technical innovation which can pioneer new ways of constituting and satisfying social demands, are understood to emerge (Kemp et al 1998; Geels and Schot 2007). They are not just about R&D, but also processes such as learning-by-doing, and building up supportive social networks including, supply chains etc. (Geels 2002: 1261). Niche technologies initially tend to have poor technical performance and are expensive. These novelties are "initially unstable…configurations" and as such niches need to act as "incubation rooms" protecting novelties against mainstream market selection (Kemp et al 1998; Schot 1998).

Technological trajectories – whether changing incrementally or radically - are situated in a socio-technical landscape (Rip and Kemp 1998), described as a set of deep structural trends. Examples given are oil prices, economic growth, wars, emigration, broad political coalitions, cultural and normative values, environmental problems (Geels and Schot 2007: 400; Smith et al 2010: 440). From the point of view of the regime and niches, the landscape level represents the "external structural context".

Within this framework, "transitions, which are defined as regime shifts, come about through interacting processes within and between these levels" (Geels 2010: 495). Niches are understood as exogenous sites of “revolutionary change”, in contrast to regimes that tend to reproduce normal innovation patterns (Smith 2010: 440). However niches can only break through, “if external landscape developments create pressures on the regime that lead to cracks, tensions and windows of opportunity” (Geels 2010: 495) (see also Kemp et al 2001, Geels and Schot 2007, Kern 2011, Smith et al 2010). The recognition of climate change can be one such pressure.

The MLP approach has usually been employed to provide case studies of historical episodes of technological changes.[11] However, Kern (2012) adapts the approach to the analysis of current policies aimed at stimulating transitions. By following this approach, we can ask how far (and why) regulatory change, especially under RIIO-ED1, is likely to drive transformations to electricity distribution networks as part of the wider decarbonisation of the wider electricity system. The framework examines key factors working at the niche, regime and landscape levels.

5.1 The niche level

The first question is how far policy has helped drive ***learning processes***. Since the core regulatory framework for networks does not incentivise long-term technological and commercial innovation, the main mechanism for supporting learning has been the “add on” schemes, including the IFI, the RPZs, but especially the LCNF projects.

The latter are emerging as a potentially important learning space, with projects ranging from voltage management and storage to dynamic thermal line rating and demand side response.[12] These will potentially support learning not only about technological innovations, such as the management of dynamic line ratings and automatic fault repair, but also contractual innovations (as with non-firm connection agreements) and consumer behaviour (e.g. Northern Powergrid’s Customer-Led Network Revolution project[13]). The requirement to make the results of projects supported by the LCNF public is important for the learning process, and the Fund now has an annual conference for sharing project findings. The LCNF is an improvement over the IFI in that it allows DNOs to collaborate with external actors, including ICT firms, suppliers and consumers. The follow-on network innovation competition mechanism under RIIO-ED1 tale this a further step and allow other actors to instigate a bid. The main limit of the LCNF in terms of its potential to support learning has been that it has continued to support projects that experiment with only separate elements of the smart grid picture, rather than an end-to-end trial, all the way from variable generation through to demand response.

A second question is how far policy has helped drive ***price-performance improvements*** in smart grid technologies and operations. It is hard to ascertain how far this is yet happening. Since most smart grid applications are still at the stage of LCNF trials, they rely on bespoke technologies (a complaint of one DNO executive was that the ICT industry is not yet mass producing affordable equipment). However, since the market here will be entirely regulation-led, ICT companies are unlikely to mass produce until the details of regulation are clear. This is especially the case such highly regulated markets, as can be seen with smart meters, where specification varies between countries.

More widely, however, some DNOs are expecting to make gross savings from smart grid solutions as against traditional ‘fit and forget’ network reinforcement and expansion. For example, UK Power Networks expects to save £135 million over the eight years of RIIO-

ED1 from solutions such as demand side response, dynamic transformer ratings and avoided overhead line reinforcements real-time thermal rating (Wilson 2013, UKPN 2013: 52). However, this should be seen within the context of UKPN's total proposed expenditure over the same period of £7.3 billion.

A third issue is how far policy has supported the transition of new technological and commercial approaches to ***market niches***. In the case of smart grids, the notion of market niches is not immediately applicable, as networks are still regulated monopolies. However, the closest analogue is how far policy helps move innovative approaches into mainstream regulated investment and operation.

Here, given the previous failure to connect innovation funding to regulated investment (e.g. Bolton and Foxon 2010, Mitchell 2008), a significant new requirement under RIIO-ED1 is that, in order to have a fast-tracked assessment of their proposed business plans for RIIO-ED1, DNOs are supposed to include an account of how learning from LCNF projects have become embedded in core business, as part of a wider smart grids strategy (Ofgem 2013b: 18). There is also a new Innovation Roll-out Mechanism (IRM) to fund the roll-out of proven low carbon innovations, with two application windows in ED1. Again, UKPN provides an example. The company is currently leading an LCNF trial on non-firm connections for distributed generators in part of the congested East Anglia region, where there are now high concentrations of wind farms. Once the trial is completed successfully, UKPN has committed to roll out this option across its operational region, which includes most of south-east England (Wilson 2013). However, the degree to which DNOs actually use the IRM more widely remains to be seen.

A final question at the niche level is how far ***powerful actors*** are part of a core group building support. It is so far not clear that this is the case. The RPI-X incentive regime offered companies stability of revenue in exchange for short-term efficiency improvements (Crouch 2006: 241; Smith 2012, Jamasb and Pollit 2007: 6170-71). As a result, DNOs tend to have particular characteristics as companies (Ofgem 2009: 21, Sansom 2010). Networks are a low-risk business, attracting capital (especially debt) at a discount. DNOs are risk-averse, and act when required to by users (for example seeking to connect) or by the regulator. They do not have pro-active corporate strategies, but react to the regulatory contract and focus on allowed revenue. The only innovation that the main regulatory regime has encouraged is innovation in short-term cost reduction, mainly through labour shedding. The firms have lacked the capacity, skills and incentives for major long-term technological and operating innovation. As a result, within DNOs, while the smart grid agenda has been embraced enthusiastically by some engineering staff, there has been little interest at Board level. There is some evidence that the higher profile of smart grids in RIIO-ED1 is beginning to change this, at least in some companies, although this change remains limited.[14]

ICT companies have long been interested in the acceleration of smart grid policy. The industry association, IntellectUK co-hosted a meeting on smart grids in 2010,[15] has a dedicated smart grids and smart metering working group, and spun-off a new organisation, Smart GridGB, to pursue the agenda. However, smart grids still have low visibility amongst more powerful actors, including senior DECC staff and politicians, who have been preoccupied with the more pressing smart meters project and above all with electricity market reform. Innovation also remains secondary to efficiency in Ofgem. Finally, some energy industry observers also argue that National Grid is actively opposed to the development of the smart grids agenda, partly because as transmission operator it would lose money if distributed generation took off in a major way, reducing the need for further transmission investment.[16]

5.2 The regime level

At the regime level, the key factors in Kern's framework are changes in rules, changes in technologies and changes in social networks (Kern 2012: 301).

In terms of ***changes in cognitive, regulative and normative rules***, the key issue is the partial degree of change in distribution network regulation, both through DPCRs 4 and 5 in the 2000s, and in the move from RPI-X to RIIO. The LCNF projects arising out of DPCR5 have raised the profile of smart grid solutions, as have the explicit requirements for a smart grids plan in RIIO-ED1.

However, the wider regulatory regime has seen more continuity than transformation. By comparison with DPCRs 4 and 5, one might expect RIIO-ED1 to represent more of a step change as it developed out of a strategic review (RPI-X@20), which in turn was a response by Ofgem to quite intense political pressure over the mid-to-late 2000s to engage with the low-carbon agenda. Ofgem itself presented RIIO as a *new regulatory model*, linked to a requirement for "unprecedented" levels of innovation by network companies (e.g. Nixon 2010) and promoting a "step change" in the way that they think about the low carbon future (Ofgem 2013: 5). However, many other observers have taken a different view, for example both the rating company Moody[17] and Consumer Focus (2009: 5) arguing that RIIO represents more "evolution than revolution" relative to DPCR5. The wind industry body, RenewableUK, took the view that the RIIO proposals represented "business as usual rather than the paradigm change required." (RenewableUK 2010: 5). One independent but informed industry observer describes it as "RPI-X with bells and whistles".[18] A more systematic analysis of the degree of regulatory change in RIIO-ED1 shows that the changes in RIIO-ED1 described above are at the level of settings of particular regulatory instruments, or the introduction of new instruments, rather than a paradigmatic shift (Lockwood 2013b).

In more normative and cognitive terms, RIIO-ED1 is still essentially price-cap regulation aimed at incentivising efficiency, and mechanisms for supporting innovation still have to be justified in terms of cost-effectiveness. At he same time, since privatisation, the regulatory regime has created an industry lobby that has become accustomed to stability and certainty, rather than innovation (Ofgem 2009: 21, Sansom 2010). There is some evidence that the more explicit treatment of smart grid investment and operations in RIIO-ED1 have begun to change the cognitive and normative rules of DNOs. The smart grid agenda, which was previously the domain of enthusiastic but junior engineering staff, has now reached board level.[19] However, evidence such as responses to consultations suggests that many DNOs remain risk averse.

In principle, the shift within RIIO to allow network companies to make a case for anticipatory investment to accommodate ***growth in low carbon technologies*** marks a significant regime change. However, the actual effect may be somewhat limited in practice, because of the nature of underlying support policies for deployment of low-carbon technologies. The general approach by Ofgem and the DNOs appears to be that the ED1 period (2015-2023) will see only very slow LCT growth, and can be seen as a preparatory period for ED2: "The take up of low carbon technologies is predicted to increase significantly during RIIO-ED2 and RIIO-ED3…The RIIO-ED1 period represents an opportunity to start to deploy smart grid solutions and get prepared for the more radical network changes that may be required in the future" (Ofgem 2013a: 17).

Importantly, this view is itself based on the government's own scenarios and policies. In developing their 'best views' of LCT growth, companies have been expected to draw on a number of scenarios for LCT growth produced by the Smart Grids Forum (EA Technology 2012), which are in turn based on scenarios in the government's *Carbon Plan* (DECC 2011b). In these scenarios (EA Technology 2012: 22), even the medium and high cases show significant growth in LCTs only from around 2020.[20] Such scenarios depend on a number of factors, including the willingness of people and businesses to adopt new technologies, but they are also very heavily policy dependent. Thus the assumption of slow uptake of LCTs before the 2020s in these scenarios effectively rests on assumptions about policy, made ultimately by the government itself.[21]

Within this framework, the DNOs have tended to take a conservative approach, almost all adopting the 'low' or 'medium' scenarios (Lockwood 2013b: 30). It is clear that companies prefer to risk undershooting LCT uptake rather than overshooting, and it also appears that they take the view that policy pressure in the form of more rapid growth of LCTs will not materialise. A senior representative of one DNO recently described the Carbon Plan scenarios as "very ambitious" (WPD 2103b: 3).

Thus overall, the current policy regime will drive technology change, both in end user technologies and in smart grid equipment, only slowly. The exception is in technologies like solar PV and wind in particular geographical areas, such as East Anglia for wind (Wilson 2013) and solar in the south-west of England where networks are already congested. In fact, for solar PV, policy has already changed since the underlying assumptions were made (2011) in the DECC scenarios, with the introduction of feed-in tariffs. Thus the 'low' scenario sees the number of PV units installed rising to just under 500,000 by 2030, but already by August 2013 over 450,000 units had in fact already been installed.[22]

A final issue is how far policy is driving changes in ***social networks*** in the regime. The closest relationship network companies have had historically has been with Ofgem. They have had no direct relationships with domestic consumers (households), and limited and heavily regulated relationships with suppliers of a purely contractual nature. Some of this pattern is beginning to change, but it is not clear how far real change will occur. The RIIO framework lays a great deal of emphasis on DNOs making a greater effort to engage with consumer groups, and RIIO-ED1 has seen unprecedented levels of consultation of such groups by DNOs, as described in their 2013 business plans submitted to Ofgem. As noted above, ICT companies have been trying to build closer relationships with network companies for a while, and the LCNF trials are giving an opportunity for closer practical working. This may also be true of DNOs relationships with suppliers.

5.3 The landscape level

As with Kern's study of the Carbon Trust, developments at the landscape level are beyond the direct influence of network regulation, so the relevant issue is how landscape developments create or constrain opportunities for the smart grids policy (Kern 2012: 306).

The most important of these developments were at the ***macro-political*** level, where climate change became an increasingly important driver for energy policy from 2004 onwards, driven in part by a wave of heightened public concern about climate change that lasted until around 2009 and party political competition to be seen to act (Carter 2010, Lockwood 2013a). Within this context, important events were the Stern Review in 2007, the passage of the Climate Change Act in 2008 following a major civil society campaign, the consequent creation of the Climate Change Committee, the creation of a new government department bringing together energy and climate change and a Parliamentary Select Committee inquiry into future electricity networks (ECC Select Committee 2008). A critical report by the now-defunct Sustainable Development Commission in 2007 questioned whether Ofgem had "kept pace with the climate change imperative and whether the government framework within which it operates is fit for the challenge of moving to a completely decarbonised electricity system by 2050", and recommended changing Ofgem's primary duty to reflect this imperative (SDC 2007: 6-8). Civil society groups joined in the criticism, arguing that Ofgem needed more staff with technical knowledge of renewables (Cary 2010: 62). Overall there was considerable political pressure on Ofgem to become more proactive in engaging with the decarbonisation agenda. However, by 2009 and especially after the 2010 general election, the climate agenda began to decline, as party political consensus broke down and economic depression eclipsed environmental concerns.

The economic crisis exposed what had in fact been an underlying ***socio-economic trend*** hidden behind the debt-fuelled boom of the 2000s, i.e. stagnant real wages for lower-to-middle income households, and increasing inequality (Whittaker 2013). These trends have heightened the sensitivity of policy makers to costs of energy, and reinforced the imperative of short-term efficiency.

The desire of individuals to take action on climate change is one aspect of ***cultural patterns*** that might in principle help aspects of smart grid operation in future, for example for demand response. However, the nearer term issue, applying more directly to smart meters than smart grids, is concern about data privacy (see Cuijpers and Koops (2012) for problems in the Dutch case). However, one recent survey by the Energy Saving Trust[23] suggests that this may not be so large a barrier in the UK, and the issue has not come up as a barrier in one of the LCNF trials involving consumers in demand side response involving smart meters.[24]

5.4 Summary

The picture that emerges from this analysis is that of a major shift in the landscape for network policy, with major political pressure on the regulator to stimulate more low carbon innovation, over the second half of the 2000s especially. The resulting response of Ofgem, first in opening up the innovation niche in successive funding schemes, and latterly in the RPI-X@20 review and the shift to RIIO, have had mixed effects. Innovation schemes, especially LCNF, have now significantly opened up the space for learning processes, and may link these to more mainstream investment and operations. However, the landscape developments of the 2000s did not, in the event, destabilise the overall regulatory regime, which remains focused at its core on efficiency.

6. Beyond MLP: explaining the persistence of the regime

The recent history of electricity distribution network policy and the slow pace of the development of smart grids raises the question of why, while major landscape developments appear to have opened up new niches for innovation, they have not destabilised the regime. This pattern represents a challenge for institutionalist approaches in political science. In such theoretical frameworks, major transformative shifts are typically explained by exogenously driven shocks or pressures that create crisis (Mahoney and Thelen 2010: 4-7; Kingston and Caballero 2009; Peters 2012: 62-63), sometimes characterised in historical institutionalism as 'critical junctures' (Cappocia and Kelemen 2007) which lead from one steady state to another. A key problem for analysing major change in response to external pressures or shocks lies in knowing why such forces do sometimes lead to major change and why they do not (e.g. Peters 2012: 78). Cappocia and Kelemen (2007: 338) define critical junctures as "*relatively* short periods of time during which there is a *substantially* heightened probability that agents' choices will affect the outcome of interest" (emphasis in the original), but argue that "contingency may imply that wide-ranging change is possible and even likely, but also that re-equilibriation is not excluded", so that "change is not a necessary element of a critical juncture" (*ibid*: 352).

Here, I argue that in the case of policy for electricity distribution networks, the degree to which greater contingency was opened up depended *both* on the exact nature of the external pressure on the institutions governing electricity distribution networks, *and* on the nature of institutional response, especially from Ofgem and the network companies.

As noted above, the regulator came under considerable political pressure to give climate change issues greater priority, not only through changes to its remit and in its guidance (see below) but also through direct criticism from civil society, academics, Parliament and other bodies. However, political pressure has not in fact been matched by *policy pressure*, especially in the form of rapid growth in the uptake of low carbon technologies which would require smart grid solutions to be developed more quickly. In detailed planning, as described above, both Ofgem and the distribution companies are working with a set of government policy scenarios in which such growth only accelerates after 2020. In this sense, the juncture of the late 2000s turned out not to be so critical after all, and the evolutionary approach to the smart grid comes as much from government as from the regulator.

Thus, in Britain, the smart grid is framed in terms of the *future* needs of policies aimed at reducing carbon emissions and tackling climate change. Here there is a contrast with other countries, which are having to learn by doing. In Denmark, over 20% of electricity is already generated by wind, and around half of the domestic sector is already provided with smart meters that can give hourly remote readings. Time of use tariffs are expected to be available by 2015 (Danish Ministry of Climate, Energy and Buildings 2013). In Germany, wind generated around 55 TWh of electricity in 2011, compared with around 15 TWh in the UK. By 2012, Germany had 32 GW of solar PV installed compared with 1.6 GW in the UK. The smart grid is now at the centre of political policy debate of Germany because it is the binding constraint now, rather than a likely issue for the 2020s.

The second factor in explaining continuity in the face of political pressure for change is the institutional configuration that emerged from the regulatory regime. The roots of this regime lie in a complex and contradictory combination of ideas described by Michael Moran (2003: 100-119). On the one hand, the ideas of the regulatory economist and the first electricity regulator, Stephen Littlechild, were highly influential in determining the design of the regime applied to the newly privatised electricity companies (Moran 2003: 104-05). For natural monopoly networks, the objective was how to regulate in ways that mimicked the workings of markets as far as possible (Rutledge 2010a: 18-20; Helm 2003: 207-09). This led Littlechild to reject the main existing regulatory model from the US of 'rate of return' (RoR) regulation, which he saw as providing no incentive for improving efficiency. Moran (2003:

105) emphasises that Littlechild was also sceptical of US RoR regulation because it required the regulator to exercise discretion in making a detailed assessment of the asset base of the regulated companies and assessing what a 'fair' rate of return is, both of which open the regulator to capture (e.g. Newbery 2003: 3-4, Jamasb and Pollitt 2007).

However, as Moran describes, Littlechild's concern to minimise the scope for discretion in a rules-based system were undermined by ideas prevalent in the culture of what he names 'club' government – a system in which British political, professional and civil service elites enjoyed considerable discretion, limited public accountability and self-governance. Club government was in crisis by the 1970s and being dismantled in the 1980s, but its norms and values were still sufficiently entrenched in government to help form the design of regulatory institutions. By contrast with the American system with its principles of public accountability and the influence of legally backed direction of regulators, the newly created British system (first seen in the telecomms regulator Oftel and subsequently copied in energy) involved an individual Director General rather than a regulatory board, and a broad framework of powers in a 'light touch' legal framework (Moran 2003: 105-06).

The resulting combination of a rather contradictory set of ideas about efficiency and discretion has had a number of effects, including the dominance of short-term monetary cost concerns in regulatory objectives and a lobby interested in stability rather than innovation, as described above.

However, probably the most important consequence is that the ability of the government to press new policy objectives on the regulator is severely limited by the latter's independence and discretion – an effect sometimes described as 'regulatory inertia' (Faure-Grimaud and Martimort 2003). When Ofgem was created in the 2000 Utilities Act, its 'principal objective' was defined in legislation as protecting the interests of not only existing but also *future* consumers, with the intent that this created an obligation for Ofgem to consider long term sustainability in its regulation of the energy industry. In 2004, this imperative was strengthened through the Energy Act which introduced the need for Ofgem to consider its contribution to sustainable development as a secondary statutory duty. In the 2008 Energy Act, the requirement to consider sustainable development was raised from a secondary duty to part of the primary duty. In the 2009 Energy Act, the language of the principal objective was altered, to clarify that the interests of consumers include the reduction of GHG emissions. In January 2010, the government issued revised guidance to Ofgem's governing Authority, sharpening the requirement for Ofgem to regulate networks in such a way that they identified and planned for a low carbon future. The new coalition Government instituted a review of Ofgem in early 2011, and currently proposes to give greater direction to Ofgem through 'Strategy and Policy Statements' which are being introduced under an Energy Bill currently going through Parliament.

However, as DECC's 2011 review of Ofgem noted, these changes to the regulator's remit and duties have "not succeeded in consistently and transparently achieving the desired coherence between the overarching strategy and the regulatory regime. This disconnect can be attributed to two characteristics of the existing legal framework: the broad scope of the duties and the weak legal status of the Guidance." (DECC 2011a: 24). The review goes on to acknowledge that the specification of Ofgem's duties has been "intentionally broad to allow the regulator flexibility". This breadth effectively leaves Ofgem to interpret policy, including trade-offs between policy objectives, in the way it chooses (ENA 2010: 2). It is unlikely that any individual regulator, and the wider institution, would want to give up this power of interpretation and discretion willingly.

7. Conclusions

This paper has attempted to explore the dynamics of change in smart grid policy in the UK over the last decade, and use the MLP framework to assess how far this change has involved effective support for innovation.

Political developments over the second half of the 2000s represented a major shift in the landscape, and in principle, important opportunities for innovation across the energy sector. In relation to networks, these developments led to a major review of the regulatory regime at the end of the decade, and the expansion of the resource for experimentation into novel techniques and contractual arrangements outside of the mainstream regulatory arrangements (LCNF). However, neither of these shifts have so far led to a significant transformation of the regulatory regime itself. In Smith and Raven’s (2012) terms, policy for niche management has so far involved shielding smart grid development from mainstream selection processes, and supporting development of innovations, but it has not yet involved empowerment of smart grid technologies by transforming the wider network regime. To this extent, the degree of innovation in electricity distribution networks in the UK will remain limited until the dynamics of regulation change. Unless or until there is a significant change of policy, this is unlikely to happen until after 2020, in contrast to other countries such as Denmark or Germany where mainstream network design is changing more quickly.

The MLP framework, adapted from Kern (2012) is useful for assessing the nature and extent of policy change. However, it is more limited in explaining why it is that significant landscape shifts have had so little impact on the regime. Here one must turn to more mainstream political institutionalist theory. I argue that both the nature of the landscape shifts (i.e. political pressure) and the path-dependent nature of institutional relationships between government and regulator, mediating that political pressure, are important.

The account here corroborates the now frequently-made critique that the socio-technical transitions framework needs a fuller account of politics (Kuzemko 2013; Meadowcroft 2005, 2009, 2011; Kern 2011; Kern and Howlett 2009; Shove and Walker 2007; Markand et al 2012; Scrase and Smith 2009; Smith et al 2010). In relation to the issues of contested spaces for innovation, politics is likely to be particularly relevant for the stages or dimensions of innovation that involve expansion into the mainstream and/or significant change to regimes, since this is where major disruption to vested interests, consumer practices and energy systems occurs. As is seen in the case of smart grid development in the UK, it is relatively easy to open up a space for experimentation (even though this did take the best part of a decade). Making the actual grid smart is a different matter, as it will require further changes to the regulatory regime, a transformation of business models amongst network companies, and a scaling up of government support policies for low carbon technologies, with concomitant costs (currently borne by consumers and taxpayers).

Notes

[1] I am grateful to a number of people who agreed to be interviewed for this paper: Phil Jones (Northern Power Grid), Judith Ward (Sustainability First), James Harbridge (Intellect UK), Rob McNamara (Smart Grids GB) and Stephen Andrews (Lower Watts). All errors of fact and interpretation remain those of the author.

[2] For example, in principle, millions of electric vehicles with batteries could be charged up overnight when wind generation is peaking but other sources of demand are low, and then those same batteries could be discharged back into the grid to help meet morning peak demand if wind speeds drop away.

[3] For more detail on the RPI-X process in distribution price control reviews, see Jasamb and Pollitt (2007).

[4] For details of the process of setting the cap see Jamasb and Pollitt (2007: 6170-71).

[5] Findings from LCNF projects are available on: http://www.smarternetworks.org/index.aspx

[6] Interview with Stephen Andrews, Lower Watts

[7] Three mechanisms are mentioned in particular: one to incentivise engagement with major customers, which includes distributed generators, one to penalise failure to meet minimum connection times and quality, and one broader measure of customer satisfaction. (*ibid*: 28-29). The financial penalties involved in the mechanisms are limited (although higher than for DPCR5), up to 0.9% of revenue in the case of the engagement incentive, and a range of payments from £10 to £270 a day under the guaranteed standards incentive (*ibid*: 80-82).

[8] The particularly thorough privatisation and unbundling of the electricity industry in the UK means that the need for such coordination is greater than in other countries (e.g. Bolton and Foxon 2010: 20; Carey 2010: 67). Ironically, although this situation implies a much greater role for government, the privatisation process itself has hollowed out the technical expertise that would be needed (e.g. IET 2009)

[9] These elements, termed 'solution sets' by the Smart Grid Forum (2011) include distributed generation (including intermittent renewables), smart meters and automated home systems, controllable electric vehicles charging and heat pumps, data handling systems, network sensing, active network management and automated intelligent network devices.

[10] This is despite the fact that in 2010 DECC issued guidance to Ofgem's governing Authority that, according to the network industry association, the regulator "should carry out its functions in a manner that will secure that an early start by network companies in identifying and planning necessary 'strategic' investments in electricity networks should take place before firm commitments from generators are required." ENA (2010: 2-3), i.e. moving away from a 'wait for need' approach.

[11] E.g. Turnheim and Geels (2012) on coal in the UK, Geels (2002) on steam ships, Verbong and Geels (2007) on the Dutch electricity system, Raven and Verbong (2007) on combined heat and power in Holland, and Kemp et al (2001) on wind power in California and Denmark, and the case studies in *Research Policy* 39, 4

[12] See the list of LCNF project documents at:
http://www.smarternetworks.org/Project.aspx?ProjectID=404#downloads

[13] http://www.networkrevolution.co.uk/

[14] Interview with Rob McNamara, Smart Grid GB and James Harbridge, IntellectUK, 10 July 2013

[15] Co-organised by the author

[16] Catherine Mitchell, personal communication

[17] http://www.utilityweek.co.uk/news/news_story.asp?id=198272&title=RIIO+is+%91evolution+not+revolution%92%2C+says+Moody%92s

[18] Personal communication, Ed Reed. Cornwall Energy

[19] Interview with Rob McNamara, Smart Grid GB and James Harbridge, IntellectUK, 10 July 2013

[20] For heat pumps, the 'low' case sees virtually no growth until 2018, and around 1 million installed by 2030. 'Central' and 'high' scenarios show much more growth, but only from 2020 onwards. The 'low' scenario for solar PV sees only a doubling in units installed between now and 2030, while the 'high' scenario shows more rapid growth but only during the 2020s onwards, reaching 16 GW by 2030. For electric vehicles, all scenarios in the set see major growth (i.e. above 1 million vehicles) only with fast-charging technology, and only from the mid-2020s onwards.

[21] As Shaw et al (2010: 5932) put it:

> "In a privatised energy system with incentive regulation and minimal scope for anticipatory investment, networks will adapt their assets to new demand and generation patterns once they have reasonable certainty of what those patterns will be. Those signals are only conveyed via requests from market participants. Thus the signals to networks are passed from government (sometimes via the regulator) to energy users and to generators and then to the networks."

[22] See data on solar PV registrations, available at: https://www.gov.uk/government/statistical-data-sets/weekly-solar-pv-installation-and-capacity-based-on-registration-date

[23] http://www.energysavingtrust.org.uk/Energy-Saving-Trust/Press/Press-releases/Price-match-UK-public-keen-to-share-and-compare-energy-consumption

[24] Presentation by Amanda Williams on the LCNF project Customer-Led Network Revolution, UKERK/Sustainability First Workshop on *GB Electricity Demand – Realising the Resource*, 16 May 2013. http://www.ukerc.ac.uk/support/0513_MP_GBElectricity

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