Has the Low Carbon Network Fund been successful at stimulating innovation in the electricity networks?

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Abstract

The physical basis of today's electricity networks are based on engineering design principles which have not changed substantially since World War 2. This has led to a stable, secure but intrinsically conservative electricity network system, characterised by small, incremental changes and technological advances. However, two major drivers are currently pushing a period of substantial innovation and change in the networks. The first of these is the need to incorporate increasing quantities of variable renewable generation at distribution level, as well as to prepare for increasing levels of electrification in heating and transport. The second comprises the new opportunities arising from the incorporation of ICT technology into the networks, including smart metering, smart appliances, demand-side participation and the development of new business models and services which facilitate active consumer engagement.

These drivers challenge the notion of an electricity grid being a simple unidirectional series of wires and transformers and make the case for a 'smart grid', in which information and communication technologies (ICT) are integrated directly into the electricity networks. These advances have the potential to transform the way customers and supply companies interact with electricity, and provide significant new commercial opportunities for communications, monitoring, control and data aggregation technologies throughout the electricity system from generation through to the consumer.

New network and smart grid technologies are a major focus in the UK's low carbon innovation strategy, with substantial public funding (£81 million p.a) provided through the Ofgem-administered Low Carbon Network Fund (LCNF) and its successor the Network Innovation Competition (NIC). These are novel programmes, both in the UK and elsewhere due to their structure, which involves consortia led by network operating companies bidding for public funds. The LCNF has recently completed its five-year funding programme, making it an opportune time to evaluate the scheme's effectiveness.

This paper benchmarks, utilising systematic analysis of the European Patent Office's PATSTAT database, the UK's performance in smart grid patenting activity over the 2000-11 period. It then examines the LCNF, through quantitative analysis of spend patterns and semi-structured interviews with key stakeholders to assess whether the LCNF has been *successful at developing and demonstrating* new technologies and practices, if these technologies and practices are *successfully proceeding* from demonstration to deployment and if the LCNF has been *open to new entrants* and more radical and disruptive ideas.

Keywords: innovation, networks, LCNF, smart grids, policy, energy

1. Background

The concept of a ‘smart grid’ or smart electricity network is essentially the integration of information and communications technology (ICT) into the existing electricity grid. New technologies and developments in the ICT sector are influencing the future development of electricity networks, allowing the possibility of greater and finer-grained control over electricity flows, and enabling new usage paradigms of distributed generation, control and consumer engagement. (DECC 2015)

There is no commonly accepted definition of the smart grid, as different countries, disciplines and industries emphasise different functions and configurations. There are, however, several characteristics that a smart grid is commonly expected to possess, though the importance and specific implementation of these characteristics are disputed. (Teh & Rhodes 2011)

- The ability to sense, understand and react to the flows of electricity through the network;
- The ability to actively integrate demand, storage and distributed generation;
- The ability to inform customers of their energy demand and usage;
- The ability to allow customers to actively participate in the energy market.

There is seen by many observers (Bichler 2012) (Xenias et al. 2014) to be a cultural difference in how the power engineering sector and the ICT sector view the smart grid. The power engineering sector often takes a *component-oriented approach* to the grid, viewing the process of implementing a smart grid to be a modernisation process involving the replacement of grid assets with improved versions while adding components such as smart metering in order to fulfil specific needs and requirements. (Bell & Hawker 2015) This process of continuous improvement is considered as a natural extension of the current paradigm, and indeed many in the power engineering sector dislike the term ‘smart grid’, viewing it as a unhelpful buzzword with a vague definition. The ICT sector, on the other hand, often sees the smart grid as a *systemic innovation* in which the increasing level and quality of communication and connectivity between system components allows the grid to be seen as a holistic system, enabling radical new business models and technologies to be developed and utilised. (Bichler 2012; Accenture 2013) In this model, the smart grid is seen as more analogous to a 3G wireless mobile network, in that by providing wide scale communication and information delivery it enables a wealth of devices and applications to provide new services to customers.

Figure 1, below, shows the major technology groupings that are considered to make up a typical smart grid system arranged by their position on the electricity delivery system. These technologies are in various stages of development and integration into the electricity networks.

This paper is structured as follows: Section 2 contains the PATSTAT patent analysis, Section 3 provides an overview of the LCNF and related activity, Section 4 contains key results from the semi-structured interviews and Section 5 provides discussion and conclusions.

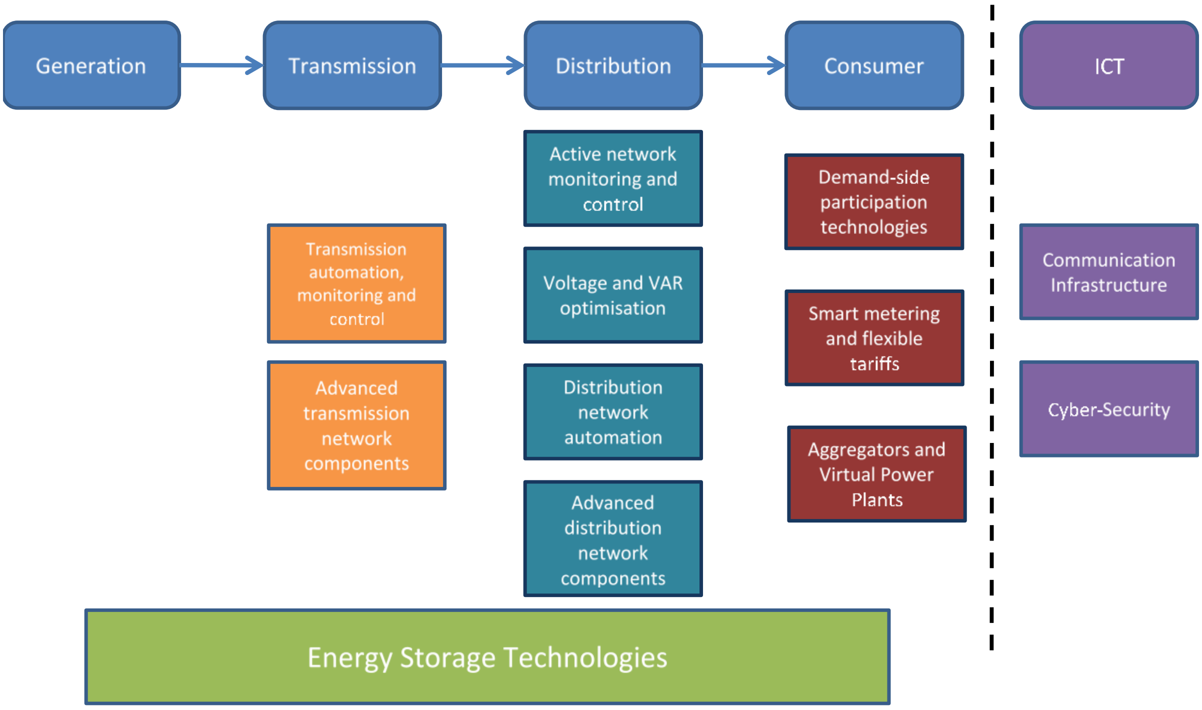

Figure 1: Technology Clusters in a Typical Smart Grid System

2. Patent Analysis

Methodology

This study uses patent filings[1] data as an output indicator of technological innovation as a means of quantifying national inventiveness with regards to smart grid technology innovation (OECD 2009; Johnstone et al. 2011) The database used for this study is the 2015 Autumn Edition of the EPO Worldwide Patent Statistical Database (PATSTAT), a database created to allow for statistical analysis of global patent data. (Johnstone et al. 2011) It is managed by the European Patent Office (EPO), and contains information on more than 90 million patent documents from over 100 countries (EPO 2016b). Patent documents are classified according to national classification systems, the International Patent Classification (IPC) and the Cooperative Patent Classification (CPC). The latter represents an extension of the IPC and was developed jointly by the EPO and USPTO in order to create a classification system that incorporates the best practices of both patent offices.

For the purposes of this study patent filings were extracted according to search strategies based on the CPC. This is primarily because its Y04S family of patent classification includes all patent documents in PATSTAT that cover ‘systems integrating technologies related to power network operation, communication or information technologies for improving the electrical power generation, transmission, distribution, management or usage, i.e. smart grids’ (EPO 2016a). Consequently, patents specific to smart grids could be extracted. The relevant sub-categories that were used are outlined in Table 1.

[1] Patent filings refer to both patents that have already been granted, and applications that are still pending at the patent office

Subclass	Description
Y04S 10	Systems supporting electrical power generation, transmission or distribution
Y04S 20	Systems supporting the management or operation of end-user stationary applications, including also the last stages of power distribution and the control, monitoring or operating management systems at local level
Y04S 40	Communication or information technology specific aspects supporting electrical power generation, transmission, distribution or end-use application management
Y04S 50	Market activities related to the operation of systems integrating technologies related to power network operation and communication or information technologies

Table 1: Subclasses of the Y04S CPC patent class

Whilst patent analysis can offer valuable insights, it is subject to a number of limitations as an indicator of technological innovation. The first is that not all inventions are patented, as inventors might choose not to patent in favour of alternative methods of protecting their invention, such as secrecy (Haščič & Migotto 2015). Furthermore, patenting is expensive, and so smaller companies might not have the resources to do so. The second is that patents represent an intermediate step in the innovation journey and not all patented inventions will necessarily reach commercialisation. The third is that the propensity to patent varies across countries and sectors, and differs by year, as patent laws and practices differ. Consequently, any cross-country and cross-technology comparison is likely to be biased towards countries with a strong patenting culture (OECD, 2009). Furthermore, a home bias exists, as domestic applicants are more likely to apply for a patent in their country of residence than non-residents (OECD, 2009).

This paper examines patent applications at the European Patent Office (EPO) and patents that form triadic patent families. Triadic patent families are inventions that share at least one priority application, which has been filed at the EPO and the Japan Patent Office (JPO) and has been granted a patent by the USPTO (OECD, 2009). Analysing triadic patent families has several advantages, as home bias in patenting activity is mostly eliminated (OECD, 2009). Furthermore, these patents are usually of higher value as the cost of patenting is high and inventors/owners will only file for protection if the patent is deemed valuable (OECD, 2009). In this study, triadic patent families were identified by combining data in PATSTAT with the September 2015 edition of the OECD Database on Triadic Patent Families. PATSTAT is the primary data source for the OECD database.

It should be noted that patent applications are published at least 18 months after filing, which creates a lag between the date of application and its publication and subsequent availability in databases like PATSTAT (EPO & UNEP 2015). The time period taken for the study when examining EPO patent applications was between 2000 and 2011, as 2011 was the latest date for which data was available for in the 2015 Autumn Edition of PATSTAT. (EPO and UNEP, 2015). The latest available data for triadic patent families is 2010 (OECD, 2016).

In terms of patent nationality, this work uses the inventor's 'country of residence'. This reflects the inventiveness of local and regional research centres, whereas the applicant's country of residence reflects ownership of inventions (OECD, 2009). Where inventors from multiple countries are listed on the patent application, a fractional count method was used to avoid double counting (OECD, 2009).

Key Results

	EPO (2000-11)			Triadic Patents (2000-10)		
	Country	**%**	**Count**	**Country**	**%**	**Count**
1	US	29.2	596.4	US	38	151.6
2	Germany	18.9	385	Japan	31.3	124.9
3	Japan	11.4	231	Germany	7	27.7
4	France	6.1	123.7	UK	3.2	12.7
5	Switzerland	5.5	111.2	France	2.8	11
6	UK	4.8	97.2	Canada	2.2	8.8
7	Korea	3.8	77.7	Korea	2	8
8	Italy	2.9	58.1	India	1.5	6.1
9	Canada	2.5	51.3	Belgium	1.4	5.6
10	India	1.7	33.7	Italy	1.1	4.3

Table 2: Top inventive countries, applications to the EPO (2000 – 11), Triadic Patent Families (2000 – 10).

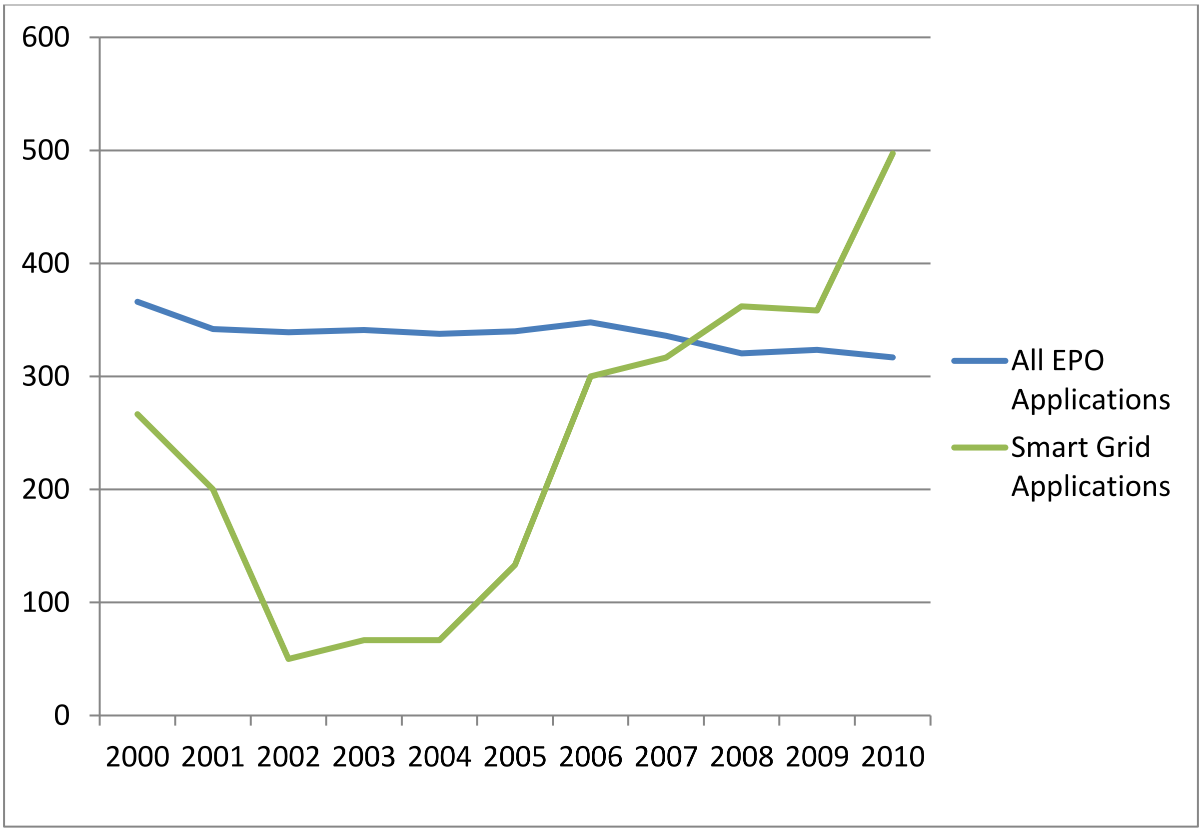

Figure 2: Smart grid patents filed to the EPO by UK inventors, indexed on 179 = 100

Subclass	Description	UK Ranking
Y04S 10	Systems supporting electrical power generation, transmission or distribution	**8**
Y04S 20	Systems supporting the management or operation of end-user stationary applications, including also the last stages of power distribution and the control, monitoring or operating management systems at local level	**5**
Y04S 40	Communication or information technology specific aspects supporting electrical power generation, transmission, distribution or end-use application management	**7**
Y04S 50	Market activities related to the operation of systems integrating technologies related to power network operation and communication or information technologies	**9**
All Y04S		**6**

Table 3: EPO rankings for the UK for Y04S subclasses: 2000-11

	Company Name	Fractional Count
1	ONZO LTD	7
2	RESPONSIVELOAD LTD	5.5
3	NEUL LTD	4
4	ROLLS ROYCE PLC	4
5	INTELLIGENT SUSTAINABLE ENERGY LTD	3
6	OPEN EN LTD	3
7	BRITISH TELECOMM	3
8	ALERTME COM LTD	3
9	PSYMETRIX LTD	3
10	BAE SYSTEMS PLC	3
11	UNIV STRATHCLYDE	3
12	ITRON INC	3
13	NGRID INTELLECTUAL PROPERTY LTD	3
14	SENTEC LTD	2
15	REACTIVE TECHNOLOGIES LTD	2
16	LANDIS & GYR AG	2

Table 4: UK patent-holding companies with more than one Y04S patent, EPO data 2000-11

Discussion

Analysis of patent applications filed at the EPO in the PATSTAT patent database shows the UK as being a significant source of smart grid patents, in the top ten of countries both overall and in each subgroup. The UK also shows a high proportion of triadic patents, suggesting that these generated patents are higher commercial value. UK patenting activity, after suffering an abrupt fall from 2000-04, rose sharply from 2005 onwards and outperformed overall UK patenting activity from 2008.

The UK ranked highest in the Y04S 20 subcategory, which involves the management and control of stationary end-user applications. This includes areas such as smart home and building control as well as smart appliances, and this is borne out by the list of top patenting companies in the UK, which is dominated by ICT and big data firms with very few entries from engineering companies. Several companies on the list have subsequently changed name, been acquired or have entered administration, with ResponsiveLoad becoming Open Energi and Psymetrix being acquired by GE. The UK ranks lower in transmission and distribution technologies (Y04S 10) and market activities and systems integrating technologies (Y04S 50), areas where it would be expected to see a greater level of innovation from transmission and distribution companies as well as larger engineering firms. Other research in this area has noted the extremely low rates of innovative activity and patent applications by UK network companies. (Jamasb & Pollitt 2015).

Overall, the UK is strong in patenting activity relating to smart appliances, end-user applications and other ICT support technologies for smart grids, and relatively weaker in areas of innovation relating to systems supporting transmission, distribution, systems integration and market activities. Patent data from PATSTAT currently only exists in a complete form up to 2011, so more recent patenting activity stimulated by the LCNF and other schemes cannot be analysed at this point.

3. UK Smart Grid Innovation and the Low Carbon Network Fund

Electricity networks have traditionally been seen as an area of mature technology and low innovation spend levels. The basic structure and technological components of a nationwide grid have not changed substantially for over sixty years and this has been reflected in the low historical R&D intensity in the UK in this sector (Jamasb & Pollitt 2015). Following privatisation, the R&D intensity of the network operating companies in 2005 was an average of less than 0.2% (CCC 2010). This low intensity was a factor of the mature technological space occupied by electricity networks as well as the RPI-X price control method adopted by Ofgem, which incentivised the regulated-monopoly network companies to pursue efficiency programmes and extended utilisation of existing assets instead of capital spend and innovation measures. In 2005, in response to concerns about the low level of innovation spending by the DNOs, Ofgem introduced the Innovation Funding Incentive (IFI) programme, which allowed DNOs to spend up to 0.5% of their revenue on R&D projects of their discretion and recover 90% of that spend, within the bounds of eligibility, defined as ‘enhancing the technical development of distribution networks’.

In 2008, Ofgem initiated the RPI-X@20 review to evaluate RPI-X for its effectiveness and appropriateness in tackling 21st century challenges. (Ofgem 2008). As a result of this review the price control mechanisms for the regulated monopolies of the transmission and distribution networks were overhauled, moving to a model, RIIO, which aims to incentivise efficient investments in innovation and assets. RIIO stands for Revenue = Incentives + Innovation + Outputs, and moves from a five-year price control settlement under the RPI-X system to an eight-year period, which it is hoped will incentivise longer-term investments. The RIIO model was utilised for electricity transmission and gas network settlement periods from 2013, and for electricity distribution from 2015.

In the interim before the adoption of RIIO for the DNOs, the Low Carbon Networks Fund (LCNF) was introduced for the electricity distribution networks across the 2010-15 price control period to address a perceived shortfall in electricity distribution network innovation spending, The LCNF was designed as a 5-year programme with a total budget of £500 million, divided into two tiers. Tier One was similar to the existing IFI scheme, allowing DNOs to recover a proportion of expenditure, between 0.5% and 1% of their revenue, on small-scale R&D projects. Tier Two, where most of the funding was concentrated (up to £64 million a year), consisted of an annual competition where DNO-led consortia bid to lead larger multi-year projects developing and demonstrating new technologies, operating and commercial arrangements. Data from the EU's Joint Research Centre (EU JRC 2016) show the striking effect the LCNF has had on the UK's public smart grid innovation landscape. Figure 3 shows that while basic R&D spend, including academic grants from the Research Councils in the UK has remained relatively low, cumulative D&D (demonstration and deployment) spend rose by £325 million over the 2010-14 period, an order of magnitude over previous years. The UK in 2014 was second in the EU, behind France, in smart grid innovation spend. (EU JRC 2016)

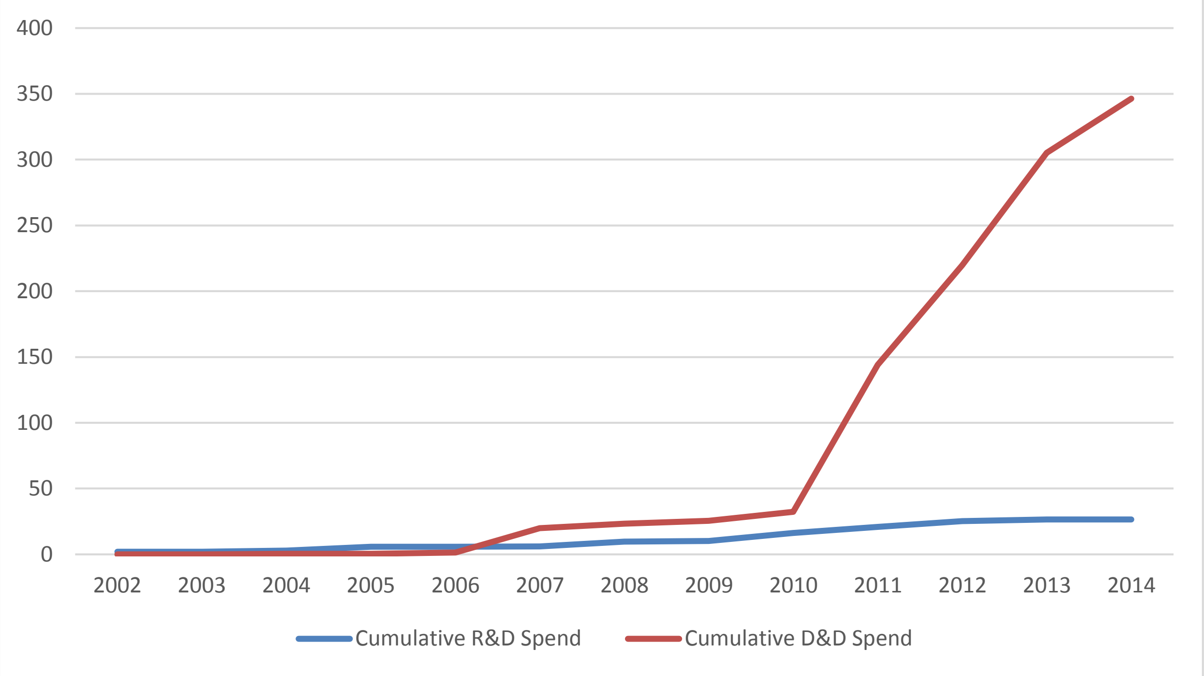

Figure 2: UK Cumulative Public Spend on Smart Grid R&D and D&D projects 2002-14 (Million £) (EU JRC 2016)

	Tier 1 Funding (£k)
Electricity North West	**£4,410**
Northern Powergrid	**£2,880**
SSE Power Distribution	**£5,050**
SP Energy Networks	**£2,330**
UK Power Networks	**£4,710**
Western Power Distribution	**£4,750**
GRAND TOTAL	**£24,130**

Table 5: Tier 1 Allocated Funding 2010-15 (£k) (Ofgem 2015)

Tier 2 Funding	LCNF Funding (£k)	DNO Contribution (£k)	External Funding (£k)	TOTAL (£k)
Electricity North West	**£29,146**	**£502**	**£3,839**	**£33,487**
Northern Powergrid	**£27,353**	**£3,039**	**£22,227**	**£52,619**
SSE Power Distribution	**£37,957**	**£307**	**£10,016**	**£48,280**
SP Energy Networks	**£11,021**	**£2,588**	**£495**	**£14,104**
UK Power Networks	**£57,453**	**£8,302**	**£10,182**	**£75,937**
Western Power Distribution	**£50,281**	**£2,555**	**£4,099**	**£56,937**
GRAND TOTAL	**£213,212**	**£17,293,954**	**£50,858**	**£281,365**

Table 6: Tier 2 Allocated Funding 2010-15 (£k) (multiple sources)

Tables 5 and 6 show the allocated funding for Tier 1 and 2 projects throughout the 5-year lifespan of the LCNF. Tier 1 funding is allocated on a non-competitive basis, with DNOs able to utilise their allowance without formal approval from Ofgem, provided it meets programme criteria. Of the £79m of Tier 1 funding available between 2010-15, £24.1 has been taken up by the DNOs, a take-up rate of 31%. Electricity North West and SSE were the only two DNOs to spend significantly above the average, with take-up rates of their allowance of 46% and 51% respectively. These low take-up rates of this non-competitive funding stream raise questions as to whether DNOs are sufficiently utilising the available resources.

Tier 2 funding was more effectively utilised – out of the total £320m budget over 2010-15, £213m was allocated, a take-up rate of 67%. UKPN and WPD were awarded the largest share of this funding, though this table does not include funding for SSE's NINES project on the Shetland Isles, which although proposed as a Tier 2 project, was awarded by Ofgem through an exceptional funding mechanism.

The successors to the IFI and LCNF Tier 1 and 2 schemes, the Network Innovation Allowance (NIA) and Network Innovation Competition (NIC) respectively, are part of the current eight-year settlement period for electricity transmission and distribution and the gas networks. Figure 2, below, shows the NIA and NIC in relation to other public innovation bodies in the smart grid innovation chain. The two schemes, similar to their LCNF and IFI predecessors, stretch across a large portion of the innovation system from applied research to late-stage demonstration and early deployment.

The LCNF, by funnelling public innovation funding through private regulated-monopoly-led consortia, is a novel innovation mechanism both nationally and internationally. Several international regulators, including those governing New York State's energy sector and the Victoria State water sector in Australia, have expressed interest in RIIO and the LCNF as a framework to improve their regulated sectors. (Buchanan et al. 2015)

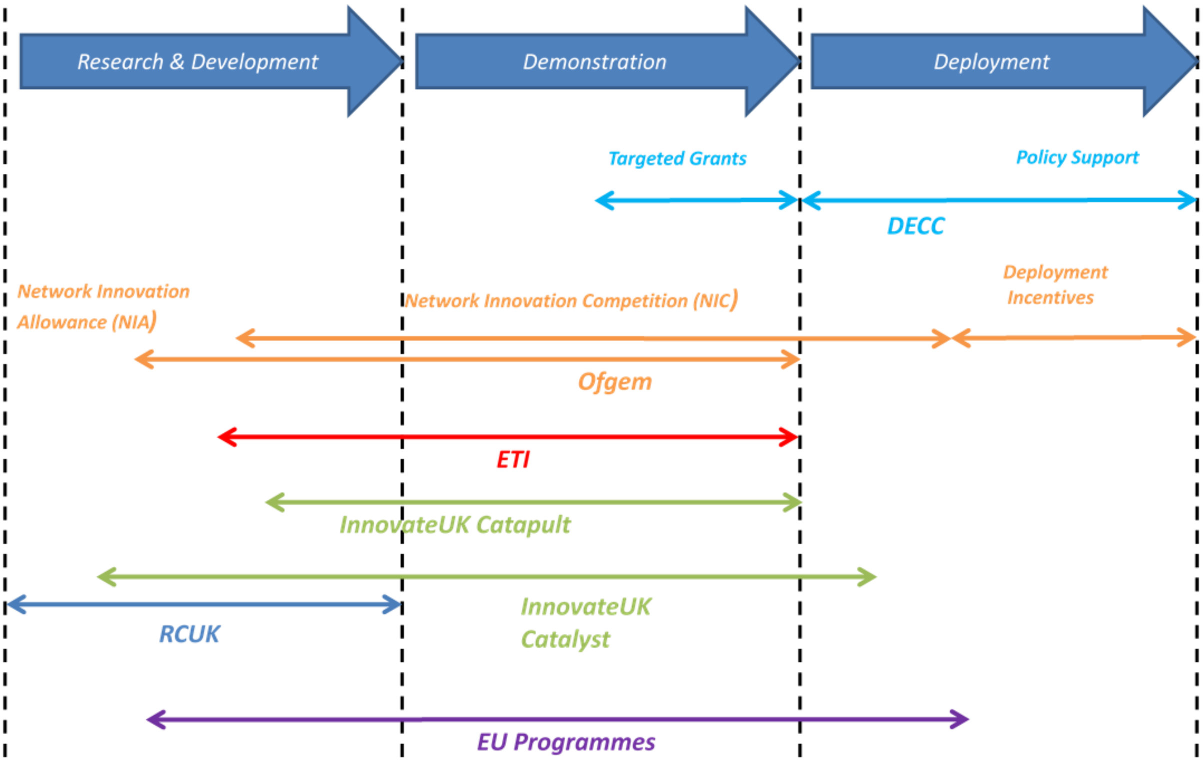

Figure 4: Innovation Landscape of Public Sector Institutions in the Smart Grid Sector

4. The Low Carbon Network Fund: Semi-structured Interviews

Documentary interviews have been conducted over the past six months with over twenty academic, industrial and policy stakeholders, ranging from high level policy figures to managers and participants in specific projects. The interviews were conducted via a semi-structured method and lasted for an hour. Questions, which were provided to the interviewees beforehand, formed a loose framework around which discussions could take place. A list of the interview questions can be found in Annex A.

Key messages from the combined interviews are summarised below, divided into four sections:

- Near and medium-term innovation challenges in the smart grid sector;
- The Low Carbon Networks Fund;
- The evolution of the DNOs in response to innovation challenges;
- The boundary between the power engineering and ICT disciplines.

Innovation Challenges

The major near-term challenges in the UK smart grid sector were considered by most interviewees to be holistic in nature, surrounding integration of components, complexity barriers and the centralisation/decentralisation of control systems. Technical innovation of individual components were considered to be less critical, as many components were at the stage of readiness for demonstration and pre-commercial deployment. Greater levels of consumer engagement and evolving the processes, procedures, rules, standards and governance of the sector were seen as important challenges.

The distribution network faces major challenges in management and operation. In the words of one interviewee; *'The transmission network needs to evolve, the distribution network needs to have a* *revolution.*' Several interviewees mentioned the transition from a distribution network operator (DNO) to a distribution system operator (DSO), which will require major changes both in the use of infrastructure assets and in the management, investment and overall mind-set of the company.

The network sector is dominated by the regulated-monopoly network companies, and therefore does not follow a traditional free-market paradigm. Different methods to incentivise innovation in this sector are therefore required. The challenge in delivering smarter grid technologies is not whether network companies are able to deliver, but is around the incentives which will be successful to push them to deploy new technologies and practices. The LCNF, RIIO and NIA/NIC were seen as ambitious and novel schemes to provide these incentives.

The Low Carbon Network Fund

The Low Carbon Network Fund was seen overall as a bold, important and necessary programme. DNOs had engaged well with the programme, setting up dedicated innovation teams and submitting a relatively wide range of bids. The LCNF has also been perceived from overseas as an ambitious statement of intent from the UK, attracting significant international interest. No interviewee expressed regret at the existence of the LCNF and all agreed that it has been a major positive step forward in innovation resource and effort for this sector.

Bid preparation was criticised for being lengthy, requiring significant resource and time. The resources required to participate in bid preparation were challenging for academics and smaller SMEs to provide, making it more difficult for these to participate in projects at the planning stage. The process by which Ofgem's expert committee selected projects, and the extent to which they take into account work going on outside the LCNF programme was described as too opaque. Large early projects such as Low Carbon London and the Customer-led Network Revolution were criticised for being too large and complex, with too many goals and an unwieldy number of project partners. More recent projects have been smaller, more sharply focused and better targeted, indicating an increasing ability and understanding of the DNOs in outlining and delivering on successful innovation projects.

Another criticism widely shared was that of a 'checklist mentality', whereupon specific criteria for success were set at the beginning of the project and rewarded by partly or fully repaying the DNOs financial commitment if met. This was seen as a problematic method of designing innovation projects, as the criteria, by not accounting for failure or for different outcomes and use cases, as well as incentivising short-term success and impact, encouraged more incremental projects where the risk of not meeting successful milestones were reduced. Academic interviewees also raised concerns at the methodological design and scientific rigour of projects, though it was acknowledged that DNOs had improved in this regard since the beginning of the LCNF. There were also some comments that the structure of the LCNF programmes seemed designed to procure and test infrastructure assets over testing socio-technical solutions, which has led to limitations in the design of some projects.

The procedures by which partners are selected for the DNO-led project consortia attracted mixed comments. DNOs do not have a common way of selecting partners for projects, with some utilising more open procurement and partnering processes than others. Partners very often need to have financial resources to participate, perhaps unintentionally creating a bias away from smaller SMEs and toward large suppliers. SMEs also raised concerns that no project partners can solely capture the foreground IP resulting from LCNF projects – for smaller companies and start-ups intellectual property rights are important when considering entering into collaborations. The structure of the LCNF prohibits third parties from initiating a projects, as projects can only by initiated by DNOs. While understandable, as projects need to be demonstrated and deployed on their networks, it was questioned by some interviewees if they needed to be involved in the initiation of every project, or if in some cases a more open auction or marketplace could be used to allow third parties to pitch ideas to DNOs.

Data outputs from the projects are openly available in most cases, though they were seen as not being well archived and curated and difficult to access and use. Reports were criticised for not following a common structure and for being too long and vague. It was suggested that curation specifications should be built into the projects as a deliverable milestone, to ensure that project partners supply good quality datasets and reports. One interviewee suggested that Ofgem is not familiar enough with data curation, including the ethical and legal constraints around some of the datasets.

Moves to deploy technologies and methods demonstrated through the LCNF seemed in some cases insufficient, with DNOs not adopting solutions developed by other DNOs' projects, and dissemination and follow-up efforts often thin on the ground. While the annual LCNI conference was praised by many interviewees, some wanted the possibility of more frequent and smaller-scale events concentrating on deploying specific technological solutions and methods. LCNF projects are funded with the intention that they will proceed to large-scale network deployment if successful, so follow-up work in this area should be a priority to ensure best value-for-money.

Concerns over the timescales of bid preparation and project timeframes were raised in several interviews, principally those with SME and industrial figures. Given the pace of innovation in some areas, principally in ICT-based consumer and aggregation solutions, one interviewee raised the possibility of a second tier of smaller, faster projects to respond more quickly to technology advances.

Multi-vector projects, combining electricity, gas and heating were mentioned several times. The LCNF only funded projects on the electricity networks, likewise the gas network NIA/NIC only funds gas projects. There is a view that multi-vector thinking and research will become increasingly important to the smart grid, with the introduction of products such as hybrid gas boilers and heat pumps as well as greater levels of aggregation and consumer arbitrage. It would be useful if future schemes allowed multi-vector projects to be funded.

A disconnect with primary research was raised by several interviewees, partly due to a focus on demonstrating short-term outcomes and impact as part of the projects. LCNF projects have tended to be aimed at high Technology Readiness Levels (TRLs), away from basic research, which tends to be higher-risk with the possibility of higher long-term rewards. While early-stage research is therefore not the best fit for the LCNF's objective to produce deployable results, there was a feeling that academics working at lower TRLs were not well connected to LCNF projects and results. Network companies have seemed to have reduced their engagement with RCUK-funded projects and initiatives such as the Centres for Doctoral Training (CDTs) since the start of the LCNF. The Energy Systems Catapult, as well as other initiatives such as the Power Networks Demonstration Centre at Strathclyde, were mentioned as attempts to bridge this gap.

Network Companies

Several interviewees remarked on a substantial culture change in DNOs over the last several years, driven by concerns over increasing network connection requests and constraints as well as the substantial innovation allowances now available. DNOs have led and paid for several workstreams (principally workstreams 3 and 7) of the Smart Grid Forum (SGF), for example. Innovation teams have been created and expanded in all DNOs, though there were concerns that the levels of integration and knowledge transfer these teams have with main operations were not sufficiently strong. DNOs are still seen as conservative companies, however. Their obligations to provide secure and efficient networks preclude radical and high-risk ventures. Incremental, not radical, change from the DNOs was expected by interviewees.

The divide between projects that should be funded by bill-payers through the LCNF and work which should be funded privately by DNOs as part of their business-as-usual investments was, according to many interviewees, not clear. There were concerns that DNOs were relying heavily on LCNF/NIC funds to support innovation, and without these schemes, which are not guaranteed by Ofgem beyond the end of the first RIIO period in 2022, the culture of innovation in these organisations would be severely reduced. As a major objective of these schemes is to foster a sustainable culture of innovation in network organisations, efforts need to be made to ensure continuity after the conclusion of the NIC.

The evolution of DNOs to DSOs, anticipated in several possible visions of a future smart grid, would almost certainly substantially alter the risk profile of the company. The risk profile of a DNO is well understood, and most of their investors tend to be pension funds and others who are interested in slow and steady returns. Would a move towards a DSO model lead to a risker profile, and how would that affect investment? One interviewee also brought up the point that DNOs have extensive expertise in capital expenditure and infrastructure investment, but less so in the operational expenditure required to run a DSO business. New skillsets will need to be developed and they may need assistance from external organisations.

Engineering and ICT

There is a mismatch in timescales between development of energy assets and infrastructure, which can often take years or even decades, and software, which can often only take months. The investment risk profiles also differ substantially, with software being much less risky due to far smaller costs in facilities, testbeds and infrastructure. Successful ICT solutions are also often developed using a ‘bottom-up’ approach, improving and expanding outwards from an initial testing point, whereas national network infrastructure is necessarily planned and standardised from a ‘top-down’ perspective. How should these approaches be melded in a smart grid development programme? It was suggested by one interviewee that parallel development systems, with integration occurring at the very end of development, could be a better solution. However, this would raise new questions around interoperability and centralised control. More centralised ICT solutions, such as the Data Communications Company (DCC) were criticised as being behind schedule and over budget. Centralised ‘big data’ solutions for monitoring and control have often been difficult for network companies to integrate and have led to mixed results.

Smart grid systems are a new and emerging sector, with open standards still under development. Underpinning all contemporary ICT standards are years of international effort by organisations such as the IEEE, and similar work is underway for smart grid systems. It was considered important that Ofgem as the national regulator should continue to be fully engaged in these efforts.

5. Conclusions

Key messages from the interviews point to the success of the LCNF as a method of stimulating innovation in the regulated monopolies of the networks, and its achievement in incentivising a culture of innovation. Evidence from patent analysis suggests that the LCNF is targeting the weakest areas of UK smart grid innovation, and indeed innovation spend in this sector in the UK in 2014 was the second highest in the EU. However, this success is tempered by concerns regarding the quality and rigour of the methodology and dissemination of learning from projects to other network operators and the public availability and quality of project results and data. There are also uncertainties as to whether this level of innovation would survive a reduction in public support.

Several key themes emerge from the interviews, which should be considered when planning future schemes of this nature. Bid preparation should be streamlined, with efforts being made to ensure projects follow rigorous research methodology and are not discouraged from riskier activities due to constraining success criteria. Projects should be able to be agile in response to unforeseen results or challenges encountered midway through research. There should be a clear line between projects which are unlikely to be privately funded, and therefore should be funded publically through this scheme, and those which should be funded privately by the network companies as business-as-usual. Partners should be selected through an open process, with the possibility of being able to initiate projects under certain circumstances. Following the conclusion of projects, more effort needs to be made to ensure datasets and reports are openly available, well curated and structured in a single accessible framework. Dissemination events and follow-up efforts should be made to confirm that successful projects move to deployment across the network and not simply in a single DNOs jurisdiction.

The LCNF has performed well at stimulating incremental improvements to address current network issues, but there are questions around the scheme’s ability to demonstrate and assess radical and disruptive innovations, particularly those originating from actors outside the conventional network ecosystem. The LCNF can be considered, as discussed in Section 1, a *component-orientated* approach to smart grid innovation. The next stage of this project will be to compare and contrast the LCNF to the Jeju Island Testbed in South Korea, a large-scale integrated smart grid project which ran from 2009-13. Fieldwork has recently been completed in Korea, and further work will compare and benchmark the two schemes in order to learn lessons for successful network innovation policy.

Annex A: List of Interview Questions.

Overarching Research Questions

1. What are the current innovation challenges in delivering a smart grid?
2. What are the roles of the public and private sectors in delivering a smart grid?
3. What have been the successes and failures of current large-scale smart grid innovation schemes such as the LCNF programme?

Detailed Questions

1. What are the major near-term innovation challenges in each of the identified technology areas, and are these being addressed?

2. What role has the public sector in play in incentivising smart grid development, both directly and indirectly?

3. How favourable are the utility companies to innovation?

4. Has the Ofgem Low Carbon Network Fund been successful at developing and demonstrating smart grid technologies?

5. What lessons can be learnt for future large-scale energy innovation programs and institutional innovations?

6. What issues have you witnessed in the operation of these research programmes, and how were they addressed?

7. How do innovation in ICT and in power systems converge in smart grid R&D, and are there tensions caused by differing innovation cultures?

8. How important is localising international products to national electricity networks? Are there possible constraints on the potential export market?

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