Sustainability First

GB Electricity Demand Project – *realising the resource*

Paper 11

How could electricity demand-side innovation serve the electricity customer in the longer term ?

Authors

Frontier Economics : Sarah Deasley, Claire Thornhill,
Julian Hentschel & Victoria Sedgwick

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Sponsored by : BEAMA ; British Gas ; Consumer Futures ; EDF Energy; Elexon ;
e-Meter Siemens ; E.ON UK ; National Grid ; Northern Powergrid ; Ofgem ;
Scottish Power Energy Networks ; UK Power Networks ; Vodafone.

Smart Demand Forum Participants : Sponsor Group ; Energy Intensive Users' Group ;
Consumer Futures ; Which ? ; National Energy Action ; Ofgem ; DECC ; Sustainability First.

Preface

Sustainability First

Sustainability First is a UK environment think-tank with a focus on practical policy development in the areas of sustainable energy, waste and water. Sustainability First undertakes research, publishes papers and organises policy seminars. It is a registered charity with independent trustees – www.sustainabilityfirst.org.uk.

Since 2006, Sustainability First has produced a series of major multi-sponsor studies on GB household smart energy meters and brings significant knowledge and insight in the fields of energy efficiency, smart metering, smart energy tariffs and demand response.[1]

The Sustainability First project '**GB Electricity Demand – *realising the resource*'** is a three-year multi-partner project (2011-2014) focusing on the potential resource which the electricity demand side (industrial, commercial and household customers) could bring to the GB electricity market, through both demand response and demand reduction.

Key themes for the project include:

- Customer Response and Consumer Issues.
- Commercial and Regulatory Issues.
- Public Policy Issues.

The project was supported in its first year under the Northern Powergrid Low Carbon Network Fund project - and thereafter for a further two years to 2014 via a multi-sponsor group.

Sponsors include : BEAMA ; British Gas ; Consumer Futures ; EDF Energy; Elexon; E.ON UK ; National Grid ; Northern Powergrid ; Ofgem ; Siemens ; Scottish Power Energy Networks ; UK Power Networks ; Vodafone.

Work is coordinated through a **Smart Demand Forum,** whose participants include the sponsor group together with Ofgem, DECC and key consumer bodies: Energy Intensive Users Group, Consumer Futures, Which? and National Energy Action.

[1] Sustainability First published smart meter papers are available on the website – www.sustainabilityfirst.org.uk

The project is:

- Evaluating and understanding the potential GB electricity demand-side resource across all economic sectors (including the role of distributed generation and micro-generation) ;
- Developing a clearer understanding of the economic value of this resource to different market actors and to different customers over the next 10-15 years ;
- Evaluating the key customer, consumer, commercial, regulatory and policy issues and interactions.

The project is developing a substantive knowledge-base, and provides visibility and thought-leadership for GB electricity demand-side issues. The project is undertaking work relevant to:

- GB smart meter deployment.
- Low Carbon Network Fund and Network Innovation Competition projects – emerging lessons & insights.
- The work of the DECC / Ofgem Smart Grid Forum & its workstreams.
- Plans for the electricity demand-side (DSR & electricity demand reduction) in Electricity Market Reform.

The work programme for the GB Electricity Demand project is being delivered through the Smart Demand Forum, through wider stakeholder events, and through twelve published papers.

The project also draws upon relevant information from demand side developments in other countries to inform its work (notably the EU, US and Australia).

Sustainability First
April 2014

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GB Electricity Demand project papers – available at www.sustainabilityfirst.org.uk	
1	**GB Electricity Demand – context and 2010 baseline data.**
2	**GB Electricity Demand 2010 and 2025 – Initial Brattle Demand-Side Model : scope for demand reduction and flexible response.**
3	**What demand-side services could customers offer?** • **Household customers.** • **Industry customers.**
4	**What demand-side services can provide value to the electricity sector?**
5	**The electricity demand-side & wider energy policy developments.**
6	**What demand-side services does Distributed Generation bring to the electricity system?**
7	**Evolution of commercial arrangements for more active customer & consumer involvement in the electricity demand-side.**
8	**Electricity demand and household consumer issues.**
9	**GB Electricity Demand – 2012 and 2025. Impacts of demand reduction and demand shifting on wholesale prices and carbon emissions.** **Results of updated Brattle modelling.**
10	**The electricity demand-side and local energy: how does the electricity system treat 'local'?**
11	**How could electricity demand-side innovation serve the electricity customer in the longer term?**
12	**The household electricity demand-side & the GB electricity markets : realising the resource.** (June 2014).

Paper 11

How could electricity demand-side innovation serve the electricity customer in the longer term ?

Part I

Part II

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Part III

Annexes

Figures & Tables

How could electricity demand-side innovation serve the electricity customer in the longer term ?

Overview

This paper sets out to consider some longer term electricity demand-side issues from a largely customer-focused perspective. At its core sits a question about how electricity demand-side innovation may best serve the customer in the longer-term.

For this paper, we define the goals of customer-serving innovation as being able to deliver on:

- **Cost –** reducing the costs to customers of moving to a low-carbon energy system;
- **Outcomes –** increasing provision of the energy services and environmental outcomes that customers want;
- **Empowerment –** empowering customers to engage in the electricity system's transformation in the way they wish; and
- **Fairness –** helping to ensure that outcomes are delivered to a range of customer groups, including the most vulnerable.

Part I – discusses some present approaches to electricity demand-side innovation funding and considers how far this is supportive of customer-serving innovation. Chapter 1 paints a very high-level picture of GB approaches towards innovation funding for the electricity demand-side (and aims simply to give a context for the discussion which follows in Chapters 2 & 3). Chapter 2 discusses the LCN Fund as a catalyst to demand-side innovation and Chapter 3 offers a limited look at the experience of some customer-facing market actors on innovation funding for the electricity demand-side.

Part II - considers two practical 'innovation' examples of automated control (chapter 4) and small-scale thermal storage (chapter 5) and discusses how in the longer term such developments may serve customers, what major technology gaps and commercial challenges stand in the way of these technologies being deployed at scale, and concludes with a high-level discussion of consumer issues (chapter 6).

Part III – briefly pulls together some general conclusions and suggested next steps on how innovation funding could serve the electricity customer in the longer-term.

In writing this paper, we would stress that its purpose lies within the context of the Sustainability First GB Electricity Demand project, and in this sense, has a limited scope. Although we consider the issue of 'regulating for innovation' in this paper, in no sense have we 'reviewed' electricity demand-side innovation funding such as the LCN Fund. Instead, we simply seek to offer some general and high-level reflections which those with an interest in electricity demand-side innovation funding, may wish to take forward in the future.

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This paper draws upon a combination of desk research and informal discussion which took place in November and December 2013. We spoke on a non-attributable basis to fifteen actors active in the area of electricity demand-side innovation. This included : two large suppliers ; two distribution networks ; an aggregator ; a trade body ; seven product developers; Ofgem and DECC[2].

Sustainability First and Frontier Economics are grateful to all those who kindly provided case-study material and other inputs to this paper. Responsibility for the paper and its conclusions rest with us.

Sustainability First & Frontier Economics.
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[2] We spoke to TSB in February 2014.

Paper 11

How could electricity demand-side innovation serve the electricity customer in the longer term ?

Part I – The electricity demand-side : regulating for customer-serving innovation

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Part I – The electricity demand-side : regulating for customer-serving innovation

Chapter 1 : Background and context : innovation funding & the electricity demand-side

1.1 Background and context

The GB electricity industry is in the middle of two major transformations, with profound end-to-end implications for every aspect of electricity sector operation and delivery. These transformations are driven by :

- The switch to low carbon; and
- The shift from analogue to digital operation.

The two are not inevitably linked, but they happen to be taking place in parallel in an industry which is still inherently conservative and, in parts, fully regulated. Each is a very significant driver for change and, potentially, for unleashing and deploying new and innovative approaches. Given the near-to-medium term costs of de-carbonisation for consumers, digital transformation would ideally be harnessed to support the cost-efficient and affordable delivery of low-carbon.

For these reasons, the topic of innovation in the context of the GB electricity sector is potentially very wide-ranging - both on the supply- and demand-sides. However, this paper has a narrow focus on **demand-side innovation and how this could best be expected to serve the customer in the longer term**. Over the past five years, two very important essentially 'regulatory' steps have been taken to support GB electricity demand-side transformation.

- **Network innovation**. There has been regulatory recognition in price controls and funding stimuli (for example, the Low Carbon Networks (LCN) Fund, Network Innovation Competition (NIC)) of the need to modernise and 'smarten' our basic network infrastructure to handle decarbonisation at the local level. This is from both a technical and operational perspective[3] as well as from a commercial and demand-side perspective (of particular interest to us for this paper).

- **Smart meter roll-out.** There has been government recognition that a national deployment of smart meters could provide a modernising platform for the GB energy sector at the retail end, capable of supporting both lower-carbon approaches and new customer-led services.

[3] This is not the focus of this paper but is being considered in SGF WS 3 and 7.

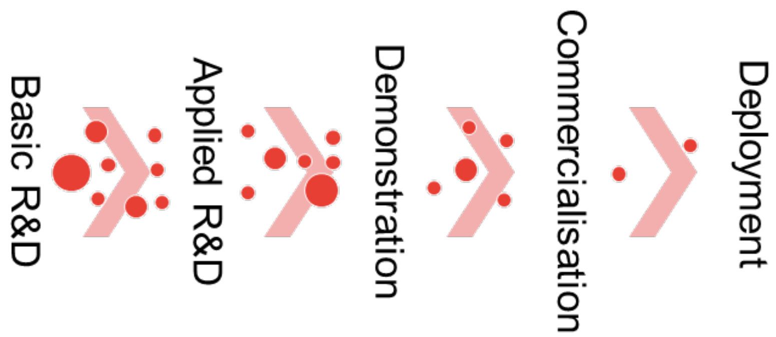
In particular, given that these two basic developments in support of the GB electricity demand-side have been 'kick-started' by approaches which are inherently 'regulated', this paper asks how successful these two basic steps are for encouragement of customer-serving innovation. The paper also looks beyond smart meters to consider other innovation developments in consumer facing products and services.

The rest of this chapter provides some very general background on innovation funding in the electricity demand-side area, simply to contextualise the discussion which follows in the rest of this paper. In particular, it outlines at a very high level the challenges faced in the promotion of customer facing innovation in the energy sector, and the interventions that are currently in place to overcome these challenges. Providing this high level overview seemed useful because it became clear in our discussions that developments in electricity demand-side innovation needed to be thought about in this wider context.

1.2 Barriers to achieving innovation

A simple linear[4] model of innovation is shown in Figure 1.

Figure 1. Linear model of innovation



Source: Adapted from Stern (2006)[5], p.349.

There are two particular features of this chain that are important when thinking about regulatory challenges to stimulating innovation.

- Learning from failure is an intrinsic part of the innovation process. Innovative ideas that are unsuccessful in a particular phase, fail to progress. Consequently, only a fraction of ideas on which basic R&D is conducted end up being widely commercialised.
- Innovation often involves multiple interactions. Although one firm may progress a technology throughout the entire innovation process, often multiple actors are involved, passing the baton as the technology matures. A single technology may be developed by several different firms along the process before being sold to a firm with access to the final consumer.

Barriers to innovation are not unique to the energy sector. Some well-known market failures associated with innovation across all sectors are described briefly in Figure 2.

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[4] We note that this is not the only framework by which to consider innovation funding. We also recognise that thinking about innovation in this linear way is a big simplification.

[5] Stern (2006), The Economics of Climate Change, http://webarchive.nationalarchives.gov.uk/20130129110402/http://www.hm-treasury.gov.uk/d/Chapter_16_Accelerating_Technological_Innovation.pdf

Figure 2. Market failures in the provision of innovation

Knowledge spillovers	**The economic benefits of innovation rarely accrue solely to the innovator, as other firms can learn from, or can copy products once they come to market. This weakens the incentive to innovate and results in less innovation than would be optimal for society as a whole**
Risk aversion	Innovation is an inherently risky process. Often the outcome, value and costs of innovation are all uncertain. Commercial firms are typically more risk averse than society as a whole, and may avoid risky innovative activity
Long payback periods	Commercial firms generally require investments to pay back more quickly than society as a whole. Payback from innovation may take many years or require high rewards. As a result, commercial firms may not be prepared to invest in innovation that society as a whole might think worthwhile.
Inadequate knowledge networks	Different incentives and time horizons apply at different points of the innovation process. Innovation can benefit from collaboration between multiple actors whose incentives and time horizons can combine to support an idea throughout the whole process. However, the valuable differences between these actors can also make it difficult to form successful partnerships
Technology lock-in due to economies of scale	Where an idea benefits from significant economies of scale, it may not be able to replace an entrenched but inferior existing technology. This problem arises when the new idea can only compete with the incumbent technology after it achieves significant scale. Because it can't compete at smaller scale, it never grows to replace the incumbent.

Source: Frontier Economics

Each of these market failures are present, to some degree, in the energy sector. For example, risk aversion may be particularly acute for networks as regulated monopolies typically attract relatively risk-averse investors. The long asset lifetimes of networks also mean that the risk of technology lock-in is heightened. For retail companies, competitive pressures may mean knowledge spillovers and long payback periods pose particular problems. For both networks and retail, inadequate knowledge networks play a role in stifling innovation, as the diversity between players across the value chain can hinder effective sharing of information and collaboration on innovative projects. The disaggregated nature of the electricity value-chain also means that the benefits of innovation are typically dispersed among different organisations, meaning that it can be hard for any organisation to capture all of the gains of an innovation investment.

In addition to the general market failures associated with innovation, the policy and regulatory landscape that the energy sector operates in has created further barriers.

- **Regulation will largely dictate innovation strategy**. There are large parts of the sector, such as the distribution networks, that are natural monopolies and therefore subject to high degrees of regulation. Incentives to innovate for these parts of the sector will therefore be almost entirely driven by the detail of the regulatory framework, rather than the market. If innovation is low on the policy agenda (as was the case for the sector up until relatively recently), other factors will drive the determination of profitability and shape firms' behaviour. In addition, because so much activity in this sector is regulated, innovation strategy throughout the value chain will be significantly shaped by regulation, regardless of whether actors sit in a directly regulated part of it.[6]

- **Multiple policy goals can block innovation**. Any regulatory framework has to balance many different objectives. Policies aimed at addressing certain features of the sector may impact adversely on firms' ability to innovate. For example, the restriction Ofgem has recently placed on the number and types of tariffs that suppliers can offer, may constrain opportunities for innovation in the retail sector.

- **Policy can distort incentives to innovate.** Innovators will respond to financial incentives and signals from policy. Where policy or market failures have distorted these incentives, innovation may not be customer-serving: it may not minimise costs, or deliver the best outcomes for customers. For example, while the externality from carbon is priced in the electricity sector[7], no carbon price is applied to domestic gas use. Firms therefore have greater incentives to innovate to reduce the carbon from electricity use than they do to reduce the carbon from gas use. This is likely to mean that there is an imbalance in innovation activity between the two fuel uses. As a consequence, the costs to customers of carbon reductions will be higher than they need to be, and the resulting reduction in carbon emissions will be more limited than it would be in the absence of this distortion.

- **Political sensitivity of the sector**. The energy sector is inevitably political with significant interest in its operation, among a wide group of stakeholders. The present intense scrutiny of the sector has resulted in increased uncertainty. This may dampen incentives to innovate if it drives companies from more risky longer term strategic investment and towards shorter-term thinking. This is particularly likely if there is a fear that new innovative investment may be criticised as unnecessary or ill-judged (for example, smart meter roll-out or IHDs), or that any profits created by successful innovation could be clawed back.

- **Capital constraints may act as a barrier to UK innovation**. Many of the major players in the energy sector operate global businesses. Where these companies face capital constraints, investment will only be made in innovation for the UK market if these companies would expect to have sufficient capital to exploit these opportunities in the event that the innovation proves to be successful.

[6] The policy change and uncertainty in the energy sector in recent years has arguably increased the risks to innovation, particularly among smaller players.

[7] The current carbon price in the electricity sector does not correspond to the Government's climate objectives. This creates a further distortion.

- **A skills gap may have developed in the sector**. In the early post-privatisation decades, regulatory focus on cost-cutting and a lack of requirement for innovation may have started to undermine the sector's ability to innovate sufficiently. Recruitment has been low and the age profile of staff in the sector has risen, with many now not far from retirement which could exacerbate the skills gap in future. In addition, the Research Councils' recent review of support for energy research notes that there is a perceived "shortfall of science and engineering graduates relative to the UK needs in the energy field".[8] There may also be a lack of *consumer facing* experience in the network businesses that could limit innovation that requires skills such as marketing or customer engagement.

1.3 Current policy interventions

It is not as though the difficulties in incentivising innovation have not been well-recognised. In response to the barriers faced by firms in these sectors, a range of measures have been introduced in GB and at a European level.

Table 1 describes the main interventions applicable to the electricity sector[9] at GB-level (with further detail in Annex 1), focussing in particular on the variation in targeting across innovation stages and areas in the value chain.

[8]Prof Jim Skea, Dr Matthew Hannon and Dr Aidan Rhodes, *Investing in a brighter energy future:Energy Research and TrainingProspectus* (London: Imperial College London, 2013), 44.

[9] Some of the funding extends more broadly than the electricity value chain. However we have tried to include those sources that relate at least in part to the electricity sector.

Table 1. Innovation funding in GB

Innovation support	Stage of innovation					Part of electricity value chain				Funding available
	Basic R&D	Applied R&D	Demonstration	Commercialisation	Deployment	Upstream	Networks & system operation	Retail	Enabling technologies	
Low Carbon Networks Fund										H
Network Innovation Competition										H
Network Innovation Allowance										H
Innovation roll-out mechanism										M
Heat storage competition										M
Energy Entrepreneurs Fund scheme										M
Energy storage innovation scheme										M
Small business research initiative										M
TSB innovation competitions										M
Catapult centres										H
Energy Technologies Institute										H
Scottish Government										M
Waste and Resources Action Programme										L
UK research councils										H
Commercial and other funding										Varies

Source: Frontier Economics

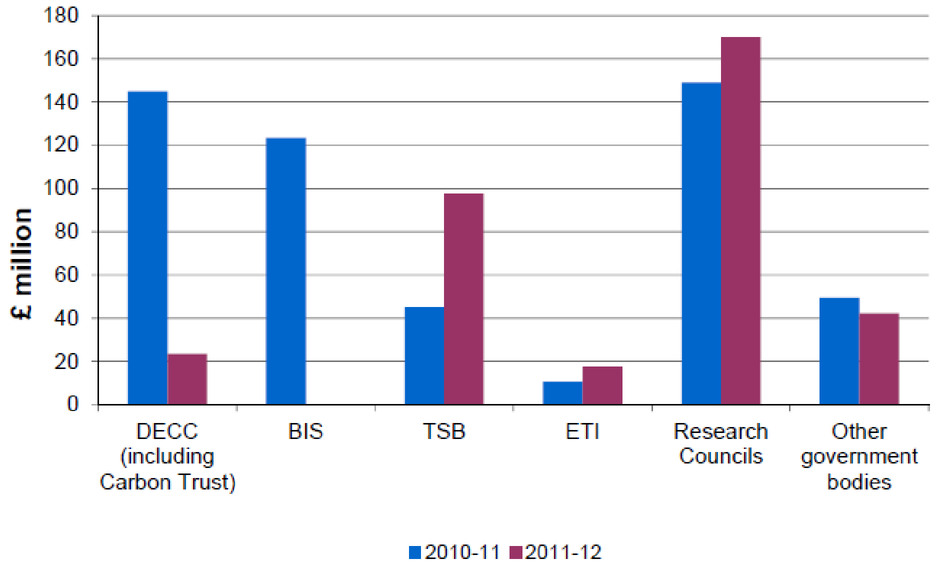
Table 1 – Innovation Funding in GB

The number and spread of these interventions raises a number of issues around the scale and scope of innovation, coordination (within GB and with Europe), and value chain coverage. We consider these issues below. In doing so we draw very heavily on the recent work the National Audit Office (NAO) has done to review innovation funding[10]. It should be noted that we have not undertaken our own assessment of these issues, nor sought to verify the NAO's findings.

1.4 Level of funding

To illustrate the magnitude of different innovation funding sources, Figure 3 shows outturn spending on low-carbon innovation by public sector bodies in the UK[11]. This excludes spending by Ofgem, which operates the main sources of innovation funding for electricity networks.

Figure 3. Outturn spending by UK public sector bodies on low-carbon innovation



Source: NAO (2013), figure 6

Note: The figures exclude spending by the devolved administrations, EU grants to UK companies and funding that comes through the innovation schemes operated by Ofgem

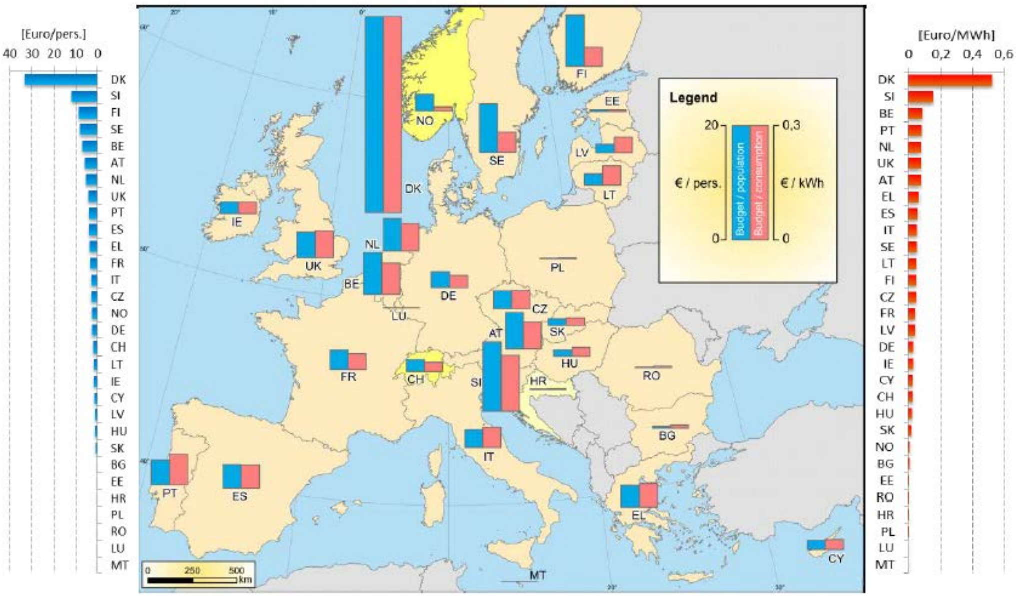
[10] NAO (2013), *Public funding for innovation in low carbon technologies in the UK.*

[11] It should be noted that the size of funding available is not always equal to outturn spending (e.g. a total amount of competition funding may not be awarded depending on the quality and type of bids).

To put the magnitude of innovation funding into international context, figures submitted to the International Energy Agency (IEA) show that in 2011 UK-wide spending on energy research, development and demonstration ranked seventh internationally (out of 22 countries), with spending lower than in the USA, Japan, France, Canada, Germany, and Australia. The figures also show a large increase in the UK's energy innovation spending from 2006 although the NAO's analysis shows that innovation spending from these sources fell by a third from £522 million in 2010/11 to £351 million in 2011/12.

Figure 4 illustrates innovation funding for smart grids in Europe on a per capita basis (blue bars) and by cumulative electricity consumption in 2002-12 (red bars). This shows that, while the UK leads in total smart grid innovation funding, its innovation spend is more comparable to other EU countries (excluding Denmark) when taking into account the size of the population.

Figure 4. Smart grid innovation funding per capita in Europe



Source: European Commission (2013), JRC scientific and policy reports, Smart Grid projects in Europe: Lessons learned and current developments, 2012 update

This is against the background of the International Energy Agency urging governments to prioritise support for energy innovation. While the NAO stated that it was satisfied that DECC's funding priorities have been supported by robust business cases, it notes that "the assessments do not address wider barriers and opportunities such as the planning system or supply chain."[12] The NAO also noted that limited commitments about the scale of innovation support beyond 2015 have caused some companies to claim that this short-term approach to funding reduced their ability to plan their organisation's long term investment strategy.

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[12] NAO (2013) p 7.

1.5 Coordination within GB

Table 1 shows that there are a wide range of interventions across sectors and at different parts of the electricity value chain. The number and varied scope of the interventions shown in Table 1 creates a coordination challenge in itself – both on the policy side to ensure funding is well targeted overall, and for the innovators, who must work out where they should focus their applications for funding. Good coordination between these interventions can help ensure the resulting innovation is customer-serving, keeping down costs through the avoidance of duplication, and delivering the outcomes that customers want through efficient targeting.

In June 2010 the NAO reported that DECC had inherited a legacy of poor coordination of a wide range of direct public support for development of renewable energy technologies from across government departments and other public funding agencies.[13] Government has attempted to rise to this challenge and provide more joined-up and cross-cutting support for innovation by re-launching the Low Carbon Innovation Coordination Group (LCICG) in 2011. Some progress has been made: LCICG has produced Technology Innovation Needs Assessments and published a strategy document in February 2014. In its more recent review, the NAO noted that it "is not yet clear whether the LCICG's efforts to provide greater transparency and improve communication from across the funding bodies are providing better support for industry. Each public funder has its own mission and approach."[14]

The LCICG has also aimed to help potential innovators navigate the variety of support mechanisms available. Despite improvements in this area, the NAO noted there remains "a widespread view that there needs to be a more joined-up approach across the innovation landscape".[15] Joint funding calls may be one way to achieve this.

[13] NAO, Government Funding for developing renewable energy technologies, HC 35 Session 2012-11, 10 June 2010.

[14] NAO (2013), *Public funding for innovation in low carbon technologies in the UK*, 8.

[15] Ibid.

1.6 Coordination with the EU

Table 2 illustrates that there are several well-funded innovation schemes available at EU level.

Table 2. EU sources of innovation funding

	Stage of innovation					Part of electricity value chain				
Innovation support	Basic R&D	Applied R&D	Demonstration	Commercialisation	Deployment	Upstream	Networks & system operation	Retail	Enabling technologies	**Funding available**
Horizon 2020										H
Eurogia 2020										M
Intelligent Energy Europe										H

Source: Frontier Economics

Barriers to accessing these schemes for UK research organisations and innovators are described in the recent Energy Research and Training Prospectus.[16] These barriers relate to high amounts of effort required up front to access the funding, requirements for multiple (and often cross-border partners), and differences between the institutional structures and funding arrangements between the UK and other EU countries. It was noticeable that these schemes were not mentioned by innovators or policy-makers during the interviews carried out for this paper.

Nevertheless, the Prospectus found that UK researchers have performed relatively well in terms of participation in EU Framework Programmes, though UK industry fared less well. Greater coordination with UK efforts could help: the Prospectus also recommends that "the UK should exert greater influence over the development of EU programmes and attempt more co-ordination of programme involvement"[17]. Following its review of UK energy innovation strategy in 2012, the IEA also recommended that the UK collaborated internationally to share costs and risks, accelerate development and diffusion, and to communicate lessons learned.[18]

[16] Prof Jim Skea, Dr Matthew Hannon and Dr Aidan Rhodes, *Investing in a brighter energy future: Energy Research and Training Prospectus* (London: Imperial College London, 2013), 44.

[17] *Ibid*

[18] NAO (2013), Public funding for innovation in low carbon technologies in the UK.

DECC has been responding to this challenge. For example, a current DECC initiative to bring together interested parties to encourage collaborative bids for Horizon 2020 funding should help the UK to receive a greater share of the available funds and contribute to a greater UK influence on the programme. The UK is also part of a new four country Bureau that is supporting the delivery of the EU Strategic Energy Technologies (SET) plan.

1.7 Value chain coverage

Table 1 illustrates that many interventions have been introduced to overcome barriers to innovation in the network sector. There are fewer interventions in the energy retail sector (which was stressed to us in discussion – and to which we return in chapter 3), and a minority of sources of funding span the full value chain, although some sources targeted at specific areas, explicitly encourage cooperation (e.g. the LCN Fund including technology, academic and NGO partners).

To some degree, it makes sense that there are greater incentives on the network side. Regulation, rather than market signals provides the bulk of incentives in the network area and therefore the burden of action falls much more squarely on policy. Ofgem has risen to the challenge in this area: its framework for setting price controls for network companies, RIIO[19], puts innovation at the forefront of the regulatory framework. In addition to the funding available through the NICs, NIAs and the IRM, shown in Table 1, the price control period has been extended to promote longer-term thinking, efficiency incentives have been designed to encourage cost savings throughout the period, and there is an expectation that innovation will form an explicit part of firms' business planning.

However, there may also be benefits for customers to providing greater funding for retail-focussed innovation schemes. Though innovation in retail can be driven by market signals, the barriers described in chapters 3, 4 & 5 apply and so less innovation than is desirable for society is likely to take place. As discussed above, innovation in energy retail is particularly likely to be judged by factors such as the perceived value and 'fairness' for customers as well as potential political and regulatory scrutiny of any increase in profits that may result from this innovation.

[19] Revenue = Incentives + Innovation + Outputs

Chapter 2 : Network innovation : LCNF (Low Carbon Networks Fund)

In this chapter we look in more detail at the Low Carbon Networks (LCN) Fund. The LCN Fund is one of the main regulatory initiatives intended to stimulate innovation in electricity networks, allowing for up to £500m of customer-funded innovation support to Distribution Network Operators (DNOs) over the five-year period 2010-2015.

We begin by briefly revisiting the rationale behind the LCN Fund's design, its original objectives and the design challenges considered when the scheme was created. We then look at how the scheme has performed in light of these objectives. This should not in any sense be seen as a full or formal review of the design or operation of the LCN Fund. Moreover, most of the projects are yet to complete. However, we do look to draw out some early lessons about how successful it may be in stimulating both demand-side innovation and the related commercial and regulatory learning that is needed to complement this.

2.1 Background to the LCN Fund

The LCN Fund was established to prepare DNOs for their role in the low-carbon economy by trying out new technology, operating and commercial arrangements.

The LCN Fund is divided into two tiers. Tier 1 covers part-funding of smaller DNO-led trials that generally do not require Ofgem's approval. Tier 2 provides part-funding for larger trials, with up to £64m allocated each year to larger trials through a competitive bid process. In both cases, there are strict requirements covering the sharing of learning and intellectual property to ensure that customer support is funding wider learning. The LCN Fund also allows for discretionary rewards to be paid to projects that are deemed to have been exceptionally beneficial. This was to try to replicate the fact that companies competing in unregulated markets are able to capture the benefits of successful innovation.

Looking back at the working papers detailing the LCN Fund's development, the use of a competitive bid process to allocate Tier 2 funding was an attempt to combine the relative certainty of 'ex ante' funding support with an element of competitive pressure between DNOs. Competition was intended to incentivise the development of original and high-quality bids, and to ensure that funds were allocated efficiently to the best bids. It is worth noting that as this competitive pressure is for approval, rather than to gain market share, the benefits of this pressure rely on the ability of the approvals process to accurately identify the best projects.

This process is undertaken by an independent 'Expert Panel' that is appointed by Ofgem, with Ofgem taking the final funding decision with reference to the Expert Panel's formal recommendation.

The original LCN Fund design proposals also intended for the £100m allocated to discretionary funding to act as "a discretionary reward to those projects which bring particular value to the challenge of preparing the networks for the low carbon economy".[20] Ofgem's "intention was that the size of this potential reward would provide a strong incentive to DNOs to dedicate the time and attention required to develop well designed, successful projects." However, this was subsequently scaled back on the basis that "the feedback [Ofgem …] received from DNOs [was] that they consider a greater guarantee of a smaller reward is more likely to be effective in bringing forward projects compared with a lower probability of getting a higher reward."[21] In response, only part of the £100m will be allocated like a prize to the most valuable projects. We discuss this further below.

[20] Ofgem, *Electricity Distribution Price Control Review: Initial Proposals - Incentives and Obligations* (London: Ofgem, 2009), 5-6.

[21] Ofgem, *Final Proposals*, 4-5.

2.1.1 LCN Fund objectives

The ultimate objective of the LCN Fund, as laid out in Ofgem's final proposals for DPCR5[22], was to encourage DNOs to prepare for the transition to a low-carbon economy. To do so, the LCN Fund was expected to promote the following outcomes.

Primarily, the LCN Fund was intended to give DNOs experience of the arrangements they should implement to "a) respond to the new network requirements that arise from a low carbon economy and b) encourage low carbon solutions such as demand side management."[23]

- However, Ofgem also wanted to make sure that the learning from this experience was shared as widely as possible and did not simply accrue to the funded DNO.
- Innovation support for DNOs was already available through schemes like the Innovation Funding Incentive. The LCN Fund was therefore specifically targeted at a perceived gap in funding for high-cost trials, which might otherwise prevent the commercialisation of learning from applied R&D.
- There was a desire to make sure that this funding comprehensively covered all necessary innovation and that "technology, commercial and network operating arrangements" were all supported.[24]
- In parallel with the desire to share learning, Ofgem was also keen that the LCN Fund fostered collaboration with third-parties, such that the DNOs became more used to integrated working and were in position to learn lessons from outside the sector.
- It was hoped that more work on innovation projects would help drive culture change within the DNOs, making them more willing and proactive to engage in risky and innovative projects.
- And Ofgem itself was keen to learn what regulatory changes were needed to enable the DNOs to effectively support the transition to a low-carbon economy.

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[22] Distribution Price Control Review 5 (DPCR5) was the control period running from 1 April 2010 to 31 March 2015.

[23] Ofgem, *Electricity Distribution Price Control Review: Final Proposals - Incentives and Obligations* (London: Ofgem, 2009), 3.

[24] Ibid.

2.1.2 Recognised design challenges

In designing a support scheme to achieve these objectives, Ofgem faced several challenges. Many of these related to the need to ensure value for money.

- Ofgem was keen that the LCN Fund was genuinely stimulating additional innovation and not merely crowding out network innovation spending from other sources, or else funding network investment that would have happened anyway.
- It was also keen, given the existence of multiple competing technology pathways and uncertainty about future technology uptake, that customer funds supported projects whose value was robust to alternative technology pathways.
- When allocating funding, it faced the challenge of developing a competitive process that would share out the funds appropriately despite the fact many of the expected benefits to innovation would be hard to quantify objectively, even if they were entirely certain.
- Finally, Ofgem sought to encourage innovation through flexible intellectual property arrangements, while still securing the greatest returns possible for customers.

In addition to these, the LCN Fund also needed to rest on a clear and comprehensive regulatory framework.

- Innovators needed to have clarity over how the returns to successful innovation would be distributed between themselves and others.
- And the LCN Fund regulation would need to dovetail with other areas of regulation, for example covering minimum security of supply standards, given the potential implications of the trials on the DNOs' broader responsibilities.

2.1.3 Regulatory framework

The LCN Fund does not operate in isolation. Although the RIIO framework was not in place when the LCN Fund was first designed, RIIO's design actively encourages innovation and seeks to ensure that learning from these trials feeds through into business as usual. In particular, RIIO extends the price control period to eight years, incorporates innovation more formally into an enhanced business planning process, and offers explicit incentives for the exploitation of new efficiencies.

The extended price control period was intended to encourage longer-term thinking about value for money and Ofgem was clear that it "expect[s] ideas on innovative ways of delivering (technical and commercial) to be included in network company business plans".[25] Ofgem was also keen, given the extended price control period, that companies be incentivised to innovate within the price control period itself. The use of an efficiency incentive rate means that "investors and consumers will share the benefits when the company delivers

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[25] Ofgem, *Handbook for implementing the RIIO model* (London: Ofgem, 2010), 26.

outputs for less money than Ofgem envisaged when setting the price control"[26] and provides a financial incentive for companies to exploit innovative efficiencies within the control period.

2.2 Experience of the LCN Fund to date

We now look at how the LCN Fund has performed to date. This is not in any sense a full or formal review of the design or operation of the LCN Fund. Moreover, many projects are still on-going and not yet complete. Indeed, Ofgem has committed to undertake a full review of the LCN Fund in the late spring of 2016. Based on our review of the available documentation and conversations with a limited number of interested stakeholders, we support the view that, at around £2/customer/year, the scheme can be expected to provide good value for money. We also raise some questions that we hope will be helpful to Ofgem and others in its longer term evaluation of the LCN Fund.

2.2.1 Is the learning becoming business-as-usual?

The LCN Fund is predicated on the idea that support for innovation will realise future cost-savings for customers when innovative techniques contribute to improved business-as-usual practices. Its ultimate success will therefore need to be judged through the business practices adopted by the DNOs, rather than specific project outcomes.

There are examples in the DNOs' RIIO-ED1 business plans of future savings being directly attributed to LCN Fund project work. However, given many of those projects had not completed by the time the business plans were being put together, many innovation savings which the Business Plans identify appear to draw from lessons and experience under the IFI scheme. Indeed it would be more reasonable to expect that the LCN Fund experience would only begin to significantly shape investment strategy for RIIO-ED2 (i.e. by the early 2020s).

Before considering some of the savings identified for the business plans, it should be noted that planned savings are often based on the contributions of multiple factors, rather than any single project. That said, the UKPN business plan notes that the DSR trials built into the Low Carbon London project were part of what contributed to committed savings of £38m in their ED1 business plan.[27] Similarly, Electricity North West cite Tier 1 funding for the Smart Fuse project as partly contributing to ED1 savings of £14.4m thanks to improved fault handling.[28] It is difficult to know in practice how important the LCN Fund is to identifying such savings,

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[26]Ibid., 84.

[27]UK Power Networks, *Our approach to Innovation Strategy and delivery* (London: UK Power Networks, 2013), 75.

[28]Electricity North West, *Well Justified Business Plan* (Warrington: Electricity North West, 2013), 8:5.

but it is at least encouraging that the DNOs are already citing LCN Fund work as contributing to their cost reduction strategies.

The RIIO framework and the eight year control period should enable DNOs to continue to implement learning from LCN Fund projects as they become available. Identifying whether there are any barriers to this happening is something that Ofgem is mindful of, particularly where the barrier is regulatory in nature.

Further attention may need to be paid to supply-chain readiness, however, if widespread deployment is to be facilitated. Large-scale trials may not provide suppliers with sufficient certainty over future demand to develop the associated supply-chain and, without the scale-efficiencies associated with developing the supply-chain, widespread implementation may not be realised.[29] This is a particular concern given that supply-chains tend to adapt better to gradual change, whereas the projections are for a step-change increase in deployment around the mid-2020s. Acknowledging this and focussing trialling during ED1 on commercialising demand-side options utilising the full supply-chain would therefore seem sensible.

2.2.2 Has there been a noticeable change in culture?

Although the LCN Fund is primarily about driving innovation, Ofgem has also sought to deliver a fundamental change in the culture of DNOs, to transform them into more risk-taking and proactive organisations that are better prepared to fulfil their role in a decarbonised energy sector.

Culture change is difficult to evaluate or quantify, but there is evidence that DNOs are changing in the way Ofgem intended. The most concrete changes involve the greater staff resources being focused on innovation. UK Power Networks' (UKPN) RIIO-ED1 business plan notes that in 2005, when its central innovation team was set-up, it consisted of just two full-time engineers and a part-time manager. More recently, it numbered around 30 engineers and support staff, including PhDs in fields applicable to distribution networks.[30] Indeed, the increased attractiveness of the industry as a place for engineering graduates to work seems to be a notable change since the LCN Fund was introduced.

However, the organisational changes involved appear to go deeper than just staff numbers. Some of the DNO business plans explain how they have created new business processes to help source, develop and embed innovative ideas within the organisation. UKPN note the creation of innovation sponsors within directorates to help facilitate the transition of innovation work into business-as-usual.[31] They also highlight the decision to decentralise

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[29] We noted in the previous chapter that the NAO has also raised concerns about whether innovation funders give sufficient consideration to supply chain readiness as part of their evaluation of funding requirements.

[30] UK Power Networks, *Innovation Strategy*, 65.

[31] Ibid., 27.

continual improvement activities to help ensure that this becomes a part of groups' day-to-day working.[32]

2.2.3 Is the balance between value for money and innovation stimulus right?

When the LCN Fund was conceived, it was in recognition of the fact that new regulatory models would be required if DNO's were to meet the expected challenges as part of the move to a low-carbon economy. These were felt to be sufficiently different from the challenges of the previous decade (that had largely been around increasing cost efficiency of traditional business models) to warrant a different approach. Ofgem therefore needed to provide a clear policy direction and set the incentive framework to achieve this.

It had two broad directions it could have taken on this.

- A managed approach to innovation support would seek to de-risk innovation as far as possible, subject to ensuring that the DNOs still have some incentive to deliver efficiently and effectively. It would be largely grant funded, with the regulator heavily involved in directing funding to the projects it feels best meet the industry's needs and then ensuring that they are delivered.

- A transformational approach to innovation support would require the regulator to attempt to replicate genuine commercial incentives, rather than de-risk innovation. Innovation would be rewarded with prizes that seek to mirror the commercial returns in an unregulated sector. The hope would be that this would transform the DNOs' business culture, and that an organisation with these characteristics would be better able to drive forward innovative activity undirected. The regulator would focus much more on the outputs from the innovation activity.

The original aim of the LCN Fund was that it would represent a transformational approach. However, there are inevitable tensions in this model, which risk a reversion over time to a more 'managed' approach.

- Ofgem is rightly concerned with ensuring that the LCN Fund delivers value for money. The concern that has been raised is that it is easier for it to be seen to meet this objective with a short-term focus on cost lines, rather than a longer-term view on outcomes.
- Regulated network utilities tend to be owned by risk-averse institutional investors who value safe and consistent returns[33]. DNOs have embraced the LCN Fund and welcomed its focus on competition to provide momentum, reputational benefits and senior

[32] Ibid., 46.

[33] Indeed, this model works well for a large part of DNOs' activities to deliver benefits to customers. The DNO's appetite for risk will be driven by the allowed cost of capital set by Ofgem as part of the price control package.

management buy-in. However, there has been some reluctance to take on more risky returns linked directly to project outcomes. As noted earlier in this chapter, the size of the prize for valuable projects was reduced in response to DNO feedback, with it being redirected to fund delivery-rewards for meeting management targets, thus lowering the risk of undertaking LCN Fund projects.

- Uptake of heat pumps and electric vehicles has been slower than was anticipated when the LCN Fund was conceived. In 2009, when the scheme was first discussed, there was a strong prospect that the networks would be facing large deployment of these technologies during (what is now) RIIO-ED1. This deployment implied significant technical and cost challenges for the networks, which innovation would help to address. While there are clusters of low-carbon technologies within each DNO region, the scale nationwide of the immediate challenge is less than originally anticipated, especially for electric heat and transport. There is a risk, as the timing of these network challenges is pushed back, that LCN Fund projects will be perversely encouraged to focus their attention on near-term problems at the expense of innovation that is more valuable for the low-carbon transition when considered over a longer timeframe.

If these tensions result in a more managed approach to innovation support, there is a risk that the LCN Fund will not deliver on a number of its goals. We outline some of the problems below.

- An increasing tendency to focus on cost inputs rather than innovative outputs. While it is important for the Expert Panel, and Ofgem, to be concerned about the appropriateness of individual cost lines within bids, this should not be at the expense of the expected value of the outputs. If firms believe that a higher cost input will lead to more valuable innovation, it may be advantageous to allow for such an approach. The original idea of a significant prize element to the LCN fund reflected this: DNOs that wanted to take on more risk on a project could have increased their cost exposure in the expectation that the learning would lead to a prize that would cover the additional costs (thus replicating more closely commercial innovation). Given that these significant prizes in LCNF are no longer available, it may be possible to set an appropriate risk/reward balance on a project by project basis through flexing the value at stake depending on the project risk as part of setting the Successful Delivery Reward Criteria.

- High costs of regulation and administration. Ofgem's understandable concern with value for money may lead to a level of regulatory intervention that itself has a high cost. While it is entirely reasonable that Ofgem considers it necessary to monitor the use of the funds, this should be proportionate. For example, the limit on second tier funding in each year is £64m, less than 2% of the average forecast total expenditure of £3,326m for the DNOs during each year of RIIO-ED1.[34]

[34] Ofgem, *Assessment of the RIIO-ED1 business plans* (London: Ofgem, 2013), 82.

- A risk of micro-management may increase risk and drive out innovation. Ofgem needs to be alert to issues around the micro-management of projects. The contract change process is an example of this. While it is understandable that there has to be a consistency between the project that was defined at bid stage and the project that is delivered,[35] it is inevitable – and desirable – that there is learning along the way. The framework should be flexible enough to allow this to be reflected in the project where it will increase its value, rather than driving the companies to undertake exactly what was specified during the bid. Further, any approach that is inflexible to project change is likely to reduce participation, given the risks associated with undertaking innovation under such a framework. This could be a particular concern for smaller collaborators who would not have the balance sheets to allow them to continue trading if Ofgem withheld funding because of changing circumstances.[36] Stakeholders with experience of both the LCN Fund and TSB funding noted the more onerous post-bid requirements of LCN Fund, although these funds each serve different purposes.

Ensuring value for money on a project by project basis is extremely important and requires Ofgem's involvement, but, equally, excessive management by the regulator may hinder attempts to change DNO culture, increase risk of participation, and, prevent the LCN Fund from delivering the greatest potential social value. It may therefore be desirable for Ofgem to see a primary goal of its funding and management of LCN Fund projects being to *maximise the total sum of learning* from these projects, while not becoming 'negligent' on determining value for money on an ex ante basis (by which we mean prior to evaluating the project outputs).

[35] Not least because of the competition approach to win funding, which could be undermined if projects were changed substantially after funding was awarded.

[36] An example of a changing circumstance might be that it was not possible to recruit customers as envisaged at bid stage (e.g. because there are insufficient customers with a particular low carbon technology).

2.2.4 Is there a case for more "joined-up" innovation support?

As we discussed in chapter 1, one of the features of the energy sector that raises challenges for innovation policy is the disaggregated supply chain. Although some potential innovations are focussed on the networks (particularly technical solutions), others (such as DSR) impact across the value chain. This was recognised by Ofgem, and fostering collaboration between the DNOs and other stakeholders has always been an explicit objective of the LCN Fund.

The bidding process for Tier 2 funding has encouraged collaborative work. For example, UKPN's Low Carbon London project involves a supplier (EdF Energy), an aggregator (Flextricity) and a transmission operator (National Grid), among others. Similarly, Northern Powergrid's Customer-Led Network Revolution pools the expertise and initiatives of a supplier (British Gas), an engineering consultancy (EA Technology) and academic institutions (including Durham and Newcastle Universities). However, there is a question whether the method of funding may be preventing a fully integrated and optimal approach to supporting innovation across the value chain.

The LCN Fund is funded by customers using the distribution network and the Fund's governance therefore requires that projects realise benefits through improvements attributable to the distribution system.[37] If value from the project is expected to fall to other parties in the value chain, they are expected to contribute funding to reflect this. However, if the value to these parties is yet to be proved by a trial, and there is no equivalent funding mechanism which they can access, this contribution is unlikely to materialise. This is despite the fact that the social and economic benefits would still be expected to reach DNO customers through other parts of the energy value chain.

One obvious example of this relates to projects involving DSR. The value proposition for household customers is largely not there at present, but this is expected to increase in future. This value cuts across a number of parties in the value chain, with the greatest benefit for customers likely to come when the value can be maximised from multiple buyers. However, while networks can access funding to test DSR solutions now, others that may value it in the future, such as suppliers and aggregators, are not able to. Yet it is often not in their commercial interest to trial in the absence of specific funding, for exactly the same reasons it is not in the interests of network companies without specific funding.

The Expert Panel's decision documents in 2012 and 2013 show that a lack of DNO-specific benefits, or lack of funding from other parties, make a bid less likely to succeed. For example, Northern Powergrid's GBFM project (involving British Gas and National Grid) was in part rejected because of an insufficient contribution from other stakeholders to reflect potential future benefits from DSR. WPD's Clean Energy Balance project and SSE's PATHS project were both rejected in part because there was insufficient evidence of DNO-specific financial benefits relative to others.

As the Panel has pointed out, in making these decisions they are following the guidance provided to them. This states that "Projects will be evaluated on the size of benefits and resulting learning from the Project that can be attributed to or are applicable to the

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[37] Ofgem, *Low Carbon Networks Fund Governance Document v.6* (London: Ofgem, 2013), 55. Indeed, Ofgem is unable to enter into contractual agreements with parties other than the network licence holders.

Distribution System versus elsewhere”.[38] It may be that the guidance needs to be amended or interpreted in a way that is more permissive of innovation that cuts across the value chain. However, we recognise that Ofgem’s vires may limit its ability to consider innovation more holistically.[39]

Alternatively, more effective coordination of the existing money available, or the use of funds specifically intended to fill the gaps in cross-cutting projects, could also help to join up the energy supply chain and focus innovation on providing smarter end-to-end solutions. None of the available funding options at the moment allow for this joined-up approach. The broader scope of the Network Innovation Competitions (NICs) that will replace the LCN Fund should help to mitigate this problem across the network companies. However, broader co-funding partnerships may be needed to help ensure that funding is available to projects with significant, but widely dispersed benefits. Although the use of multiple funders will inevitably complicate the process, attempts to improve coordination already exist, for example in the form of the LCICG. This Group could consider whether it is feasible to effectively fund cross-cutting work in the current funding landscape and consider how joined-up working, for example on DSR, can be facilitated.

[38] Ibid.

[39] We also note that as with the wider debate around Green levies, there is a question whether, even absent a legal constraint, such funding is best met through energy customers’ bills or from general taxation. While energy customers and tax payers are largely the same people, the burden can differ, with funding through energy bills likely to be more regressive in nature.

2.2.5 Is knowledge being shared most effectively?

One of the main aims of the LCN Fund was that learning should be actively shared to the benefit of all DNOs and their customers. There are positive signs that this is the case: the learning events and LCN Fund Annual Conference are very well attended and papers and much research has already been published in a short space of time (available via an ENA portal[40]).

However, there are some questions about whether we are getting best value from the learning generated and appropriately incentivising the participation of intellectual property holders. These concerns can be grouped under four headings.

- Usability of the data: A number of LCN Fund projects are generating significant volumes of customer-facing raw data that could have wider value. It seems important that, subject to privacy constraints, this data is made available in a form that others can easily use and interpret. At present, with projects on-going, this data is not generally available. The onus will be on project closedown processes to ensure that detailed datasets are published for others to make use of in an anonymised and useable form, and that appropriate custodial arrangements for the data are in place when projects end.

- Presentation of results: how far might a "warts and all" view of project learning be encouraged by the process. Specifically, might information that is shared show a bias to cover successes - and can we recognise approaches which may turn out to have provided poor value for money? A bias may result because the DNOs themselves are not comfortable with presenting learning about the problems they encounter. Alternatively, it could result from a *perception* that Ofgem may be harder on projects that depart from the original learning set-out in the bid, which may be the case if the learning is that the method is not a success. It would be a shame if this was so : learning from encountering unforeseen difficulties can be just as valuable as learning about success. This was recognised by the NAO in its recent report: "Successful innovation programmes by their nature should encourage experimentation and therefore permit a range of outcomes and a degree of failure."[41] Indeed, Ofgem recognised this when the scheme was set-up: "In the context of innovation, we need to recognise that some innovations will fail but that lessons from failed initiatives may have some positive benefits for the networks".[42] We understand that this is still Ofgem's intent : Ofgem may wish to challenge or penalise failure or inefficiency in approaches to project management, but not the outcome of the innovation being tested. Ofgem may therefore wish to proactively ask what and how DNOs have learnt from the challenges they have faced, so that this can be disseminated as a learning experience for others.

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[40] ENA Smarter Networks Portal – www.energynetworks.org/electricity/smart-grid-portal/ena-smarter-networks-portal.html

[41] NAO (2013) p29.

[42]Ofgem, *Regulating energy networks for the future: RPI-X@20: Working paper 2: Innovation in energy networks: Is more needed and how can this be stimulated?* (London: Ofgem, 2009), 11.

- Knowledge dissemination and gap analysis for GB plc: As the number of 'smart' and electricity demand-side trials and projects grow and more information becomes available, looking across projects is likely to become both more challenging and more important[43]. DNOs are individually incentivised through the RIIO framework to look across projects, both to inform their business plans and then to realise efficiencies during the price control period. Lessons from some of the major customer-facing LCN-funded projects will certainly help understanding of how the whole electricity system and value-chain benefits (so, not just network benefits) can be delivered by integrating different demand-side approaches [44]. However, pulling together thematic learning from across projects is also likely to be more widely beneficial. This may be through helping inform DECC and other departments about the implications of these trials for policy development, or informing other funders (such as the TSB) about where there may be gaps in the research that they could plug. It may also provide valuable information for innovators, who could be well placed to exploit the GB learning domestically or internationally to the benefit of GB plc. Moreover, Ofgem and the Expert Panel will need this wider learning on an ongoing basis to be confident that a project bid adds new knowledge when it undertakes future evaluations. At present there is no clear responsibility to 'curate', draw out and promote thematic lessons across different projects. This is both a question of how responsibilities are perceived and also a funding issue. The Smart Grid Forum and the LCICG should consider how this might best be achieved at reasonable cost.[45]

- Flexible intellectual property arrangements: The current LCN Fund governance arrangements make clear a willingness to consider alternative intellectual property arrangements, while also setting out Ofgem's default position. However, it is clear that some stakeholders still feel that innovative firms who depend on the development of intellectual property[46] will not engage in LCN Fund projects, especially given the comparatively attractive arrangements available through TSB support. To-date, to the best of our knowledge, none of the bids for Tier 2 support has ever requested bespoke intellectual property arrangements. Ofgem may wish to consider whether the current approach is working as intended as part of its planned review of the LCN Fund.

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[43] An example of where this is done in another sector is the pharmaceutical and health-care sectors. The Cochrane Collaboration (www.cochrane.org) is an internationally renowned not-for-profit body, which conducts systematic review and meta-analysis of trials. A core secretariat function is funded on a limited basis by governments, foundations, universities and public bodies and the work is conducted by others in the field. Its broad objectives and principles include evidence-based lessons, gap analysis and feeding lessons into policy-making.

[44] And lessons from LCNF projects are already actively shared and fed into the work-streams of the Smart Grid Forum (esp WS6) – and as well as into the Sustainability First GB Electricity Demand project papers and Smart Demand Forum meetings.

[45]We also note that the EPSRC has recently funded a network TEDDINET www.teddinet.org to promote cross-fertilisation and thematic analysis among 22 university 'smart' projects. UCL also has an EPSRC funded 'energy epidemiology' project. Finally, there are also TSB plans for an Energy Systems Catapult which should also help to identify those areas (technical, commercial, policy, regulatory) where prospective demand-side market development may face particular unknowns or uncertainty.

[46] The reality is that projects will not get internal sign-off without IP safeguards within those firms involved in product development.

2.2.6 Is there a bias towards technical innovation?

The LCN Fund set out to fund trials covering the full range of technology, commercial and network operating arrangements. However, respondents to Ofgem's two-year review of the LCN Fund suggested that support for commercial innovation was lacking.[47]

The small number of successful bids each year makes it hard to draw conclusions about tendencies in favour of either type. However, there are reasons to believe that it may be easier to get funding for technical innovation and, once the funding has been obtained, there are fewer risks associated with such projects.

Approvals for Tier 2 funding need to be publically justified because the funding decisions made determine how customers' money is spent. The need to legitimise funding may naturally bias decisions away from commercial trials, which typically provide less obvious physical or measurable return for the money spent. It is often harder to justify payment for human capital or for incentive payments than it is for new physical infrastructure.

Further, once the funding has been obtained, a project that is largely based on a technical solution may be easier to manage. For example, there may be less uncertainty around predicting the procurement of a technical solution to trial compared with understanding how a customer engagement strategy will turn out in practice. This may make DNOs more likely to propose technical solutions.

But even if such a bias is understandable, can it be appropriate? The time lag between trials and the use of the learning allows for changes to the energy system that can undermine the value of a trial's results. The relative difficulty involved in understanding and modelling the impact of these system changes on human behaviour suggests that commercial trials are particularly susceptible to having the value of their results undermined over time. In comparison, technical learning is more likely to remain robust to system changes. However, there may be an argument that DNO's need more incentive to trial commercial arrangements, (especially those which involve other parts of the value chain) given that these are further away from business as usual. Indeed, this is consistent with the view that the scale and number of challenges facing the energy sector mean that a broad portfolio of support is likely to be required.[48]

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[47] Ofgem, *Decision on the Low Carbon Networks Fund Two Year Review* (London: Ofgem, 2012), 2.

[48] The NAO note that this is the approach recommended by the International Institute for Applied Systems Analysis in its Global Energy Assessment in 2012 (NAO (2012) p12).

2.3 Lessons to be considered during the proposed Ofgem LCN Fund review

The LCN Fund outputs and outcomes are still in their infancy and although much interesting electricity demand-side material is being generated, it is premature to know how valuable the long-term learning generated will be. However, the available evidence supports the view that, at around £2/customer/year, the scheme can be expected to provide good value for money.

Experience of the LCN Fund has helped not only to improve the scheme itself but also to shape Ofgem's approach to innovation in general. Ofgem consulted on the functioning of the LCN Fund after both the first and second years of its operation. It used this process to gradually refine the Fund and, in particular, the bid selection process by, for example, improving the interaction between bidders and the Expert Panel. It has also drawn from its experience of the LCN Fund to design the broader innovation framework of the Network Innovation Competitions, whose wider scope may help to address some of the difficulties in funding innovation projects that cut across the value chain. As such there has clearly been regulatory learning related directly to innovation stimulus and the UK's regulatory framework on network innovation is increasingly seen as world-leading.

Further, looking at how the scheme has performed to date does provide some insights into how DNOs are changing and some lessons to be learned for future innovation support.

One notable success is the change to DNOs' culture and the degree of collaboration with external partners. Innovation has clearly become a greater focus for senior management in DNOs and this is reflected both in the way DNOs organise themselves internally and how they communicate their work externally: both with stakeholders and the regulator. Greater internal resource is being dedicated to network modernisation and innovative work, and there are systematic efforts to embed new learning in the everyday business.

The Tier 2 process provides concrete examples of DNOs working together with third-parties. Many projects involve several third-parties and almost all involve partnering with an academic institution. Yet, the increased stakeholder engagement does not appear to be limited to the bid process itself, and encouraged by ED1, the DNOs' business plans show how broader processes of stakeholder management have been developed.

Yet these early successes do not imply that future support should not change. Our main lessons concerning the demand-side to be taken forward into any review of the LCN Fund, or innovation policy in the energy sector more generally, are as follows.

- There may be a need to award innovation funding in such a way that is truly able to join up the energy supply chain and focus innovation on providing smarter end-to-end solutions. Available funding options at the moment do not readily allow for this joined-up approach, but, because of the industry's unbundled structure, this is where some of the biggest demand-side challenges, knowledge gaps, and unknowns sit. Broader co-funding partnerships may help ensure that funding is available to projects with significant, but widely dispersed benefits.

- While ensuring value for money on a project by project basis is extremely important, excessive management by the regulator will hinder attempts to change DNO culture, increase the risk of participation and prevent the LCN Fund from delivering long-term value for customers. There may be a particular issue achieving the balance between holding bidders accountable for the approach they set out in the bid documentation and allowing the projects to adapt to new information and learning as it arises. Any approach that is inflexible to project change is likely to reduce participation, given the risks associated with undertaking innovation in such a framework. This could be a particular concern for smaller collaborators. If Ofgem saw a primary goal of its funding and management of LCN Fund projects to be to maximise the total sum of learning from these projects, while not becoming 'negligent' on determining value for money on an ex ante basis, rather than the other way round, this may strike the right balance.

- All project knowledge, good and bad, should be shared openly in a form that third parties can understand and use; and commercial or IP constraints on data sharing should be very narrowly drawn.

We see value from an increased focus on getting more from the sum of the parts of the different schemes. More could usefully be done to curate thematic lessons from across different LCN Fund projects. This is both a question of how responsibilities are perceived and also a funding issue. The DECC / Ofgem Smart Grid Forum and the LCICG should consider how this might best be achieved at reasonable cost. Alternatively, the companies themselves could work collaboratively to synthesize learning across projects for this wider purpose, although they may not voluntarily undertake this in the absence of it being treated as allowable expenditure. The companies, together with Ofgem, therefore need to give this issue further thought.

Chapter 3 : Customer Facing Innovation

In November and December 2013 we spoke on an informal and non-attributable basis to fifteen actors active in the area of electricity demand-side innovation. This included: two large suppliers ; two distribution networks ; an aggregator ; a trade body; seven product developers (large & small) ; Ofgem and DECC[49].

In particular we aimed to understand and explore:

- The state of play on automation and small-scale thermal storage within both households and commercial properties
- To what extent the technology was ready and whether smart meters were a pre-requisite.
- Whether there was a supply chain and / or a value proposition in place or a customer pull to drive take-up; and
- How far innovation in these areas was seen to be sufficiently incentivised / driven through existing funding pots and regulation – and, if not, what action government or others might take to improve this.

Chapter 3 pulls out points made to us in discussion with market actors in connection with the supply-chain, the demand-side value proposition, customer 'pull' and how far customer-facing innovation, including for automated household control or small-scale thermal storage, may be sufficiently incentivised[50]**.**

The points noted in this chapter are not put forward as 'definitive' – but rather aim to reflect where there seemed to be some element of 'consensus' across the topics discussed.

[49] We also spoke to TSB (Technology Strategy Board) in February 2014.

[50] Part II of this paper pulls out discussion points on the first two topics

3.1 Is there still a problem with making the business case for taking technologies forward and, if so, where may innovation funding be most important?

The customer-facing actors with whom we spoke were largely focused on developing demand-side technology and / or business models in the areas of smart appliances, controls, displays and DSR. Some areas are already commercialised and continue to develop : in particular, in the areas of consumption feedback and smart 'intelligent' thermostatic controls for heat and hot-water (in GB, largely for gas heating & hot water).

The following reasons stood out on why intervention was regarded as necessary to incentivise customer-facing innovation in the electricity demand-side area :

- **Household customer demand-side pull –** there is little or no 'pull' currently from small customers for demand-side technology - although most felt that customers would be inclined to embrace innovative technology in the demand-side area once they saw good reason. The uptake of HPs and EVs has been slower than expected and so is not driving demand-side pull from customers. The high levels of household PV might be expected to drive demand-side innovation and technologies (batteries, thermal storage) – but other than a few trials this does not seem to be the case : arguably because (1) too little account to date has been paid to supply-chain constraints; and (2) the resulting network costs are socialised across all customers rather than these costs falling directly on those who may originate them.

- **Supplier or other business-case is absent –** a 'scale' market is some way off. In our discussions, there seemed to be a general consensus, other than for 'market advantage', that the GB household demand-side presently offers little by way of readily deliverable or accessible value-proposition for energy suppliers[51].

- **Smart meters are meant to catalyse a market in services -** but timeframes are somewhat uncertain and a clearer understanding will be needed of how DSR and smart services will evolve in conjunction with the smart meter system (discussed at length in chapter 4).

- **The costs of entry to household DSR are high for both large and small players**[52] : unit-costs are high against the presently deliverable benefits – though it was felt that costs may be brought down both by importing standards from other sectors which are already IP-enabled, and also by scale.

[51] i.e. on the wholesale side - see more detailed discussion of business case issues in chapter 4.

[52] Both industry & non-industry actors

- **Small innovators noted additional problems looking to move their products into 'business as usual'** :
    - Access to customers invariably entails partnering with an established market actor.

    - The understandable driver to demonstrate value at every level of decision-making in this sector, may encourage an approach to procurement which is unduly narrow, prescriptive or rules-based – potentially leaving genuine innovation and creativity as a secondary consideration.

    - SMEs looking to invest in retail-related R&D – and to sell products into the energy retail sector – face capital constraints (and especially so where energy retailers themselves are also subject to pressure on R&D-related spend).

    - Innovators are accustomed to taking & managing risks. However, significant risks were noted - both supply-chain and reputational - for small companies who may develop customer-facing or other products for innovation-funded projects (the LCN Fund was cited) – but which at project close may not be carried forward, even where a device has trialled 'successfully'. The knock-on becomes an issue for UK plc too - where small developers may find their international marketing hampered by being unable to demonstrate how their product has converted into business-as-usual at home.

- **Innovation funding will remain a very important 'bridge' where significant policy and regulatory silos persist on the demand-side. For example :**

    - To fund customer-facing (so, retail-related) R&D which can bring together innovation which *combines* a technology, behavioural & commercial focus.

    - To improve mutual understanding between smaller innovators and established industry actors and to bridge any 'culture clash' (TSB's Energy Systems Catapult is expected to help).

    - To join-up the policy 'no-man's land' which sits between energy efficiency, the demand-side and distributed generation. For example to tackle storage or community-level demand-side problems (storage competition and community energy funds notwithstanding).

    - To develop end-to-end demand-side innovation including cost-optimisation across fuels.

- **Policy and regulatory uncertainty make access to demand-side innovation-funding at the near-commercialisation stage more not less important** : a number of actors described the tensions they saw as innovators, created by being dependent upon a rather cautious and cost-conscious regulated environment to kick-start innovative customer-facing investment at scale (for example : displays ; the CAD ((the smart-meter linked 'smart home' devices)). For smaller developers / innovators working in a fast-moving environment like consumer electronics, external delay and / or changes to specification – perhaps not factored into original risk estimates - can cause major problems relating, inter al, to cash-flow , access to credit ; and supply-chain. These risks can be significantly compounded where an externally imposed delay could result in obsolescence of the product being developed. Equally, innovators may need to understand more about the highly 'regulated' environment in which they are operating.

- **Gaps in innovation funding schemes :** In discussion about differentiation between the different innovation funding schemes and any gaps, some felt that there was little clear distinction between the kinds of demand-side project funded by the research councils, DECC, BIS / TSB or the LCN Fund. They also felt that, in practice, most funding was awarded to technologies which were arguably approaching commercialisation. In the sense that this might improve general understanding of the practical problems and risks around commercialisation, this was generally not judged as problematic.

There were quite strongly held views among the different kinds of market actor about the relative benefit to them of the LCN Fund or TSB funding.

- **LCN Fund** : was seen as good for opening up new partnership arrangements – and seemed to work well for some larger technology or other players. As noted, in chapter 2, the LCN Fund, given its governance arrangements, is not 'able to fund customer facing innovation which spans the full value-chain' unless parties other than DNOs contribute sufficiently to project funding. For smaller players, LCNF was felt to create a number of challenges, including for example, around IP, highly demanding deadlines and material business risks attaching to delay, project change and non-delivery.

- **TSB funding** : the smaller innovators actively liked TSB approaches to funding as a way to support commercialisation of customer-facing innovation. Some of the particular strengths seen from the viewpoint of these smaller players were :

    - TSB funding – viewed as : comparatively free of unnecessary bureaucracy & 'strings' ; good for leveraging additional funding and for collaborating; and, ability to retain intellectual property.

    - TSB's Small Business Research Initiative: judged a good procurement model designed to solve a specific problem at a specified upper cost level via a competition. Bidders were more likely to think pro-actively about the problem to be solved – rather than match a set of rules (i.e. rules-based perhaps less effective at 'problem solving').

    - TSB Competitions, Incubators and 'Hackathons' : strong appreciation that these are : 'themed' ; good at promoting multi-party collaboration.

- **EU funds :** actors we spoke to did not express a particular interest in EU funding programmes for project support.

3.2 Who will be leading the customer facing innovation?

In discussion, the topic of customer trust was raised as a potential brake on demand-side innovation.

However, established players felt that many of their customers are in general open to new and innovative technologies and demand-side approaches – and that such developments perhaps point the way to re-defining customer relationships for the future.

Others felt that third parties, including aggregators, local authorities or other community players may become increasingly involved in partnerships with energy companies (suppliers, networks) wishing to promote demand-side activity at the household and community level. Third parties who are small, local or not-for-profit may therefore continue to need access to innovation funds - unless and until sufficient value becomes available from new demand-side revenue streams to create a strong customer pull.

It was felt that customer facing brands outside the energy sector (communications, IT, software development, data exploitation, retail goods, retail banking) would find the customer-facing parts of the energy sector a 'natural' market in which to bring both their experience and balance sheets to develop innovative goods and services with demand-side applications. This is already starting to happen without innovation funding.

3.3 What role will customer data play?

Access to granular data about customer consumption patterns - and development of new commercial applications from the detailed insight which this data will offer - was widely felt to represent the major 'innovation win' - and a powerful new commercial driver.

The smart meter and the DCC arrangements are generally regarded as a main route for potential universal access to customer data. In practice, detailed consumption data is rapidly becoming accessible with or without smart meters.

- **Data without smart meter** : examples exist, including at least one example in the GB market, which (with customer consent) makes use of monitoring equipment clamped to the 'tails' of a non-smart meter for wider data analysis. Pattern-recognition of the data so obtained, enables generic analysis of consumption data down to the *individual-appliance level* (via recognition of appliance 'electronic signatures') [53] – so enabling new and detailed insights into different consumption practices and patterns and so development of new customer-facing applications.

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[53] For example : SSE partnership with Onzo on the i-Plan monitor.

Also, paper accepted for Energy Policy. 'Is Disaggregation the holy grail of energy efficiency ? The case of electricity'. K. Carrie Armel, Abhay Gupta, Gireesh Shrimal & Adrian Albert. Stanford University.

- **Data via smart meter** : the design of the GB household smart meter arrangements enables third-party access (with customer consent) to price and consumption data from the meter system (potentially at 10-second resolution). This will allow more granular household customer data to become available *via the smart meter system* than so far in other countries [54]. This 'unique' GB smart meter data environment could therefore be expected to drive innovation services – both on the energy demand-side and more widely. Inter al, smart meter data will feed into development of sophisticated predictive models to inform design of 'rules-based' intelligent controls - capable of shaping some very bespoke demand-side approaches – and enabling effective and innovative tools to come to market – capable of delivering benefit to both market actors and to consumers. Attractive to the customer in the sense that such 'intelligent' developments may allow automated demand control without discernible disruption / inconvenience to them - while also being 'sensitive' to their individual needs and so offering a sense of 'control' (such products are already in the market).

GB customer data was therefore felt to have a far-reaching innovation and commercial value – not just for actors in the electricity sector – but for those interested in exploiting new smart services. Some areas already being commercialised include : smart heating controls ; design of new 'apps' downloadable to smart phones & tablets ; appliance condition monitoring (to flag imminent failure of fridge, boiler pump, heat pump etc); assisted living monitoring ; security and smoke alarms ; 'occupancy mapping'; home security etc. Such developments will occur without further innovation funds.

[54] Including more than via the US Green Button scheme, which we were told, has not noticeably delivered new services.

3.4 Is there a clear and coherent vision / strategy for demand-side innovation?

In discussion for this paper, in the context of the 2050 carbon target, it was clear that the *potential* for customer-facing demand-side innovation is readily pictured.

However, it was generally felt that there is still little common understanding of:

- How the household demand-side might develop in practice as smart meters roll out by 2020 – and then ahead to 2030.

- The likely costs and benefits of household demand response in 2020 and 2030.[55] This was seen as a major gap, with little grasp or consensus as to the relative 'high value' demand-side areas on which to focus effort in the near-to-medium term (e.g. which parts of the electricity supply chain (networks, wholesale markets, system operation) ; which appliances (electric heat, wet appliances) etc.

- How the market in customer-facing goods and services may therefore develop, including the supply chain.

A recurring theme was that there is presently neither a generally understood chronology or a 'forward-looking' framework which captures in a very high-level way how the GB electricity markets, and within these markets the electricity demand-side, and especially the household demand-side, may evolve going forward [56].

[55] For example, a need to revisit an initial household demand-side scenarios paper for DECC by Redpoint, Element and Baringa. August 2012 – and build upon it further.

[56] For example, akin to the Smart Grid Vision and Routemap presently being developed by the DECC / Ofgem Smart Grid Forum

Paper 11

How could electricity demand-side innovation serve the electricity customer in the longer term ?

Part II – How will demand-side innovation serve the customer : automated control and thermal storage

Part II – How will demand-side innovation serve the customer : automated control and thermal storage

Introduction

In Part II, we have focused on a key practical question in terms of where innovation is known to be needed to enable successful long-term development of the electricity demand-side. Namely :

How can innovation can help deliver *a good operational match* between patterns of customer electricity use and the costs and prices in the wholesale electricity markets and underlying network costs in ways which can help to support affordability.

With this question to the fore, we chose to look at two electricity demand-side examples where innovation *from a customer viewpoint* should be transformational in creating a general better overall match between supply and demand. For different reasons, neither are yet being deployed at scale as 'new innovation'. These are:

- **Automated control** – by creating a better 'end-to-end' match between customer usage and the short- and long-run variability of wholesale costs and prices and network costs without customer detriment (cost-efficiency, comfort, convenience).

- **Household-Level Thermal Storage –** a low-cost 'buffer' to enable a better match between non-despatchable renewable energy output - and periods of low and high-customer demand.

Further development and innovation in both these areas could contribute a material change for the customer by (1) solving technical and / or commercial problems which stand in the way of delivery at scale (2) and so, in principle, increase net benefits for customers.

Part II therefore looks at each of these separate 'innovation' examples in turn - and concludes with a discussion of likely customer attitudes.

Chapter 4 : Electricity Demand-Side & Automated Control

4.1 Automated control – definition, potential customer benefits and timescales

4.1.1 Automated control – definition for this paper

Automation may entail :

(1) a customer consenting to some or all of their electrical load being directly controlled remotely by a third party - and / or
(2) that a customer controls their own load in such a way that it responds in a pre-programmed and / or 'intelligent' way to cost-optimise.

For simplicity's sake for this paper, we have considered automation largely in terms of (1) above : namely that a customer *consents to remote control by a third party* of their appliance, their home or their building - under pre-agreed conditions that include two-way communications - with the explicit aim of allowing their electricity supply to be controlled in a way which will result in a lower end-bill than otherwise[57]. The customer may or may not have over-ride arrangements, depending on the nature of their agreement.

In practice, as controls become ever-more 'intelligent', option (2) could become the norm in offering 'bespoke' customer control plus cost-optimisation.

We have also restricted our discussion of automated control to measures explicitly intended for demand-side response (so, automated response in relation to some kind of price-related signal[58]) – rather than to automated energy efficiency measures[59].

[57] This could be via a critical peak tariff, rebate, load-management tariff etc

[58] Direct or indirect

[59] Though smart energy efficiency measures may well become a first main step into smart home systems. Also, there may well be an increasingly grey line between smart energy efficiency and smart DSR. So, for example, we do not discuss lighting controls (e.g. movement sensors for household lighting) – already widespread in commercial Building Energy Management Systems. Similarly, developments such as voltage optimisation.

4.1.2 Automated control - potential customer benefits

In principle, automated control holds out the prospect of major demand-side advances for customers. The most commonly promised customer benefits are :

- Lower-cost approaches to electricity system management - without compromising supply security and resilience.
- Convenience
- Comfort
- Autonomy and empowerment

We return to the critical question about how customers may view potential developments in electricity demand-side automated control in chapter 6. Self-evidently, without strong customer 'pull', engagement and 'buy-in', the benefits which automated control at scale may eventually offer, are unlikely to be realised.

The following are possible areas where automated control could be expected to deliver a step-change in demand-side customer benefits, especially affordability :

- **At the level of the electricity system -** delivery of *a good and reliable operational match* between patterns of customer electricity use – and wholesale costs and prices and underlying network costs[60].

- **At the level of the individual customer –** combining price-related information with 'intelligent' automated control while able to take account of customer preference for comfort, time-of-use and convenience for their appliance-use (including for heat and hot-water).

- **Turning individual customers – and / or communities - into 'prosumers'** - combining price-related information and 'intelligent' automated control of : consumption (including for heat and hot-water), and potentially, own-generation, and storage.

- **At the building level - both commercial buildings and the home – by starting to *combine* automated approaches to (1) electricity demand-side activity and (2) energy efficiency in single 'control packages'**: so, combining electricity demand-side cost-optimising controls together with automated approaches to energy efficiency (eg boiler controls, movement sensors for lighting) to maximise cost-savings.

Development and successful application of automated control is therefore a basic building block and 'enabler' for far-reaching demand-side innovation – opening new options, channels, and choices for customers to engage should they so wish.

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[60] Example : NESTA 2013. Dynamic Demand Challenge competition. Brought forward fifty innovative ideas for balancing the electricity system in a renewable world – now five finalists. http://www.nesta.org.uk/project/dynamic-demand-challenge-prize

4.1.3 Automated household control – potential timescales

End-to-end automated control to support the cost-efficient operation of the electricity system is not new, but *widespread* adoption of digital control for demand-side purposes will nevertheless take time.

Thirty years ago, integrated utilities in the UK, France, the US and elsewhere had successful load-management schemes with direct control of electric water heaters and / or electric heating in customers' homes, by use of radio signal or ripple control (to shift load to off-peak times, and, also some frequency control). Latterly, in the US and Australia with heavy summer commercial and household cooling loads, there have also been developments in remotely-controlled digital programmable thermostatic controls, to curb the afternoon cooling peak.

The most established GB example of household automated load-control continues to be the now historic Economy 7 arrangements, to charge-up storage heaters and hot water tanks at off-peak times. We discuss this in detail in chapter 5.

Looking to the future, it is easy to envisage that the powerful mix of wireless communication, massive computing power to process customer data, coupled with digital control and sensors at every level of the electricity system - will in the end transform the entire electricity infrastructure end-to-end - and with it the GB demand-side.

However, in discussion, the practical reality was felt to be that we may yet be some ten or fifteen years off until automated applications for the electricity demand-side at the home level become common-place. Interestingly, (and should the lessons of history remain relevant in this new technology context – and perhaps they will not), it could take very many years before a tipping point is reached and the fully automated smart home becomes the 'new normal' [61].

[61] Observer article. 25 August 2013 : 'Silicon Valley can't spur innovation on its own – the state has a vital role'. William Janeway notes that there was a fifty year 'tipping point' before new 'applications' and widespread commercialisation followed the original infrastructure innovation : for 'mail-order' to follow the railways ; for mass distribution of electrical appliances after Edison's first electric plant.

Although smart-systems for in-home automated control are being installed today in some new dwellings by national housebuilders, for wide-spread penetration – i.e. across the entire housing stock – we may well need to see smart meters, wide-spread offers of retail tariffs for load-management (plus their uptake) – plus many more smart readily controllable electrical appliances on the market.

4.2 Automated control : innovation trends and trials

4.2.1 GB I&C customers

Where technical and commercial conditions warrant it, most I&C load-turn down activity is already remotely automated (but not necessarily all) [62].

However, with the exception of TRIAD activity, the I&C demand-side still only has relatively limited turn-down activity (by contrast to the demand-side participation of back-up generation). Some main examples of GB load turn-down today in the I&C sector are commercial arrangements to provide fully automated frequency services into the Balancing market. These include the automated 'dynamic demand' services of HVAC systems and chillers in the retail sector, in public and commercial buildings, and in water sector pumping[63].

A recent press item also suggested that National Grid may offer to pay commercial customers for an automated 'Turn-Up Service' to use electricity during the middle of the night to save on wind-related night-time constraint payments. Examples cited – pumping water to holding tanks at off-peak times ; heating (or chillers) in a warehouse[64].

4.2.2 Building-level energy management systems which integrate automated demand response

The detailed focus of chapter 4 is household demand-side innovation - as this is generally further away from commercialisation than the I&C sector.

In discussion however it was evident that one major area for innovation on the I&C customer-side relates to installation of automated controls in commercial buildings which are capable of responding to electricity market demand-side signals in an integrated way at a *building-level*. This may achieve two things :

- A relatively near-term step-change in GB I&C demand-side approaches and participation
- Successful combination of the management in commercial buildings of energy efficiency *together with* the electricity demand-side via **commercial building energy management systems** (BEMS).

[62] Sustainability First. Paper 3. Industry Customers. What demand-side services could customers offer ? September 2012.

[63] E.g. Open Energi – www.openergi.com

[64] Process Engineering. January 2014. Online article : 'National Grid is considering paying major energy users such as process plants to use electricity at off-peak times' & 'National Grid plans to pay businesses to use wind power at night' FT (hard copy). 8 January 2014.

BEMS are well-established automated control systems for heating, ventilation and air-con, including control of building temperature and lights. For the future, there is increasing interest in the scope to integrate BEMS systems with controls for electricity demand-side 'turn-down' – potentially with the capability of providing demand-side services – directly into different parts of the electricity market (Balancing, Capacity, Network fault management). Many building energy management systems are proprietary, but in discussion we were told that this in itself was not an obstacle to integration of automated demand response systems.

The SEPD Thames Valley Vision ADR project[65] - (LCNF Tier 1) - is an example of an Automated Demand Response project providing demand-side services to the distribution network from three commercial buildings in Bracknell (see box).

The EPSRC has funded two research streams over a period to look at transforming energy demand through digital innovation[66] . The TEDDI programme has funded 22 projects to explore opportunities afforded by ICT to improve energy demand management – including some projects to develop automated controls in commercial buildings. [67] The EPSRC and TSB have also just launched a new call for research projects into energy management in non-domestic buildings and indicate that their funding collaboration is 'because it has been recognised that work is required across the whole research landscape'. [68]

DECC has also supported projects which will support DSM in commercial buildings under their £35 million Energy Entrepreneurs Fund [69]. Last, also for the non-domestic building sector, DECC recently commissioned consultants to produce a technical 'forward look' to end-2020 of the energy supply and energy management products and services likely to become available using smart and advanced metering to end-2020.

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[65] SSEPD Close Down Report. Honeywell I&C ADR : Demonstrating the functionality of automated demand response. SSET1004. October 2012

[66] The EPSRC funds 22 university projects to explore opportunities afforded by ICT to improve energy demand management – including a number of projects developing automated controls in commercial buildings. The joint £20 million-plus funding streams are : TEDDI -'Transforming Energy Demand through Digital Innovation' - and BuildTEDDI 'Transforming Energy Demand in Buildings through Digital Innovation' . The EPSRC has recently set up a TEDDI Network to encourage cross-fertilisation among these projects - see www.teddinet.org

[67] See Building Management TEDDI project (Strathclyde) ; CTech project (Nottingham, Southampton) ; CURRENT – energy use & savings potential on Lancaster University campus (Lancaster).

[68] Energy Management in Non-Domestic Buildings. September 2013. Call for research projects by the Research Councils UK Energy Programme (RCUKEP) for 'academic-led' research and the Low Impact Buildings Innovation Platform of the Technology Strategy Board (TSB) for 'business led' research.

[69]

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275101/EEF_Company_and_Project_Summaries_Phases_1_2.pdf and http://www.kiwipowered.com/pr18.html

Commercial Buildings : Building Energy Management Systems and DSR Development for GB.

In the next decade or so, many commercial Building Energy Management Systems in GB may therefore start to integrate with some form of DSR communications – especially where the BEMS are being installed into new commercial buildings.

There is an active debate about whether there is a need for common wireless standards for DSR in commercial buildings (see box).

Given the research effort noted above, one useful next step may for a GB-level discussion about the potential merit or otherwise of developing common wireless communication standards relating to DSR for commercial buildings. These standards are likely to need to comply with any parallel developments at an EU level, and would need to integrate with commercial off-the-shelf BEMS.

If common communications standards for DSR in commercial buildings – able to readily integrate with commercial BEMS packages - do indeed evolve, then there may well be no explicit need to 'regulate' via the Building Regulations (or perhaps via the London Mayor's planning powers) – which, seemingly, they have recently done in California. Nonetheless, a debate about voluntary approaches to communications standards for DSR for commercial buildings versus more regulatory approaches may be worthwhile.

4.2.3 New business models at the commercial building level - capable of combining DSR and Energy Efficiency to benefit commercial customers.

Commercial approaches, which can successfully bring together the new demand-side revenue streams which are becoming available with energy efficiency programmes such as the Green Deal (Commercial and Household), seem an area ripe for commercial innovation.

Initially this is likely to be more material for the I&C sector. New business models capable of breaking through administrative silos, which can combine different revenue streams and bring together financing from both the demand-side and the energy efficiency side could help towards delivering an outcome that is 'greater than the sum of its parts' (D1 & D2). This seems to be an area where further research funding could make a useful contribution in considering possible GB business-model approaches for successfully combining DSR and EE in commercial buildings. (see box for US example). The question of split incentives between owners and tenants of commercial buildings, would still need to be resolved however.

SEPD Thames Valley Vision ADR project[70] - (LCNF Tier 1) - Automated Demand Response project : providing demand-side services to the distribution network.

SEPD's trial in three commercial buildings in Bracknell was designed to demonstrate an end-to-end demand response service to the distribution network to shift peak-load. Honeywell equipment was used : this included their licensed DRAS (Demand Response Automation System) ; a DR 'gateway' which is the physical box which sits in the building - and interfaces between the building management system and the DRAS (1) to receive instructions of a demand-side event and (2) instructs the BEMS to load-shed ; software modifications to the BEMS ; an interface to the meter to monitor the DR results ; a broadband connection to the building [71]. Network 'events' trialled were on both an individual and aggregated basis. The load reduced was largely through control of Heating, Ventilation and Air-Conditioning systems and the load 'available' to shed therefore varies with time-of-day and time-of-year . Modelling for the project by Imperial College based on trial results estimated an aggregate potential peak load shed across the three buildings in summer of at least 460 kW and 100 kW in winter. One interesting conclusion from the modelling was that summer loads (largely cooling and chilling) may have more available 'flexibilty' than winter loads (largely heat-related). The trial demonstrated the technical potential of building level ADR, plus the ability to 'engage' with commercial building managers at a reasonable cost. The trial will now extend to a larger sample of buildings (~30).

From a customer engagement perspective the Bracknell trial offers some interesting insights, including : the value of engaging with a local authority ; customers indicated that they would either expect the intervention to offer savings on overall energy use – or they would require an incentive to participate ; 'higher-level' management sponsorship increased the ambition level of the maximum agreed load-shed ; participants were interested in the load-shed experiences of the other participants ; an ADR event may also lead to new scheduling to save energy as well as shift-load (eg on a Friday afternoon) ; the maximum potential for load-shedding varied significantly in each of the three buildings trialled ; BEMS providers may wish to charge for changing their BEMS software ; a standard form of contract to offer to ADR customers may be worthwhile in the future.SEPD concluded that the ADR trial had succeeded in its initial goals, but that there was a need for further research before Building ADR could be adopted as an alternative to network investment on a business-as-usual basis by a DNO. In particular it would be important to : predict the amount of ADR available at any given time ; optimise despatch of a portfolio of ADR responses across a group of buildings – either geographic or 'virtual' ; automation of ADR triggers by the network.

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[70] SSEPD Close Down Report. Honeywell I&C ADR : Demonstrating the functionality of automated demand response. SSET1004. October 2012

[71] Honeywell Building Solutions' Automated Demand Response technology is in use in the US, Asia, Australasia & China.

Development of common communications standards for automated demand response in commercial buildings [72].

Historically in the US, just as in the UK, much load-management and demand response capacity was built around proprietary and non-integrated communications technologies – ranging from very basic one-way radio signal networks (used to turn down thousands of home air conditioners), to phone-call and email alert systems to big industrial and commercial customers to manually turn down big loads.

Open ADR is one of a number of a communications standards being developed in support of the US 'smart grid'. It is a communications specification which was published in 2009, and was seven years in development by the Demand Response Research Center at Lawrence Berkeley National Laboratory, in the wake of the California electricity crisis.

The aim was to develop a non-proprietary and standardised demand-response interface which uses a common communications 'language'. The OpenADR system communicates price signals from market actors for a demand response event and works in an integrated way with the energy management system in a building. The building energy management system uses the signals to control different forms of demand-response : peak-load shedding, frequency response etc.

OpenADR is in use by California's three large investor-owned utilities to connect their I&C customers to their demand response programmes. It is also in use elsewhere in the US, Canada, Europe, Asia and Australia.

From July 2014, the Building Energy Efficiency Standards (2013) of the California Energy Commission[73] , will require that new non-residential buildings over a certain size incorporate 'Occupant Controlled Smart Thermostats' (OCST) to allow a building occupant to set and maintain a desired temperature *and to voluntarily participate in utility demand response programmes*. The Energy Commission Code specifies that all OCSTs support : a communications interface ; a user-display & interface ; and, an HVAC System Interface. The Code requires that the communications system should be capable of receiving and automatically responding to at least one standards-based messaging protocol (& which *inter al* may be OpenADR), to enable demand response after receiving a demand response signal.

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[72] Drrc.lbl.gov/openadr

[73] California Energy Commission. Code of Regulations. Title 24, Part 6 & Joint Appendices JA5. Pp 195-201. http://www.energy.ca.gov/title24/2013standards/rulemaking/documents/final_rulemaking_documents/44_Final_Express_Terms/2013_JA_FINAL.pdf

Example : new business models capable of combining DSR and Energy Efficiency at the commercial building level to benefit commercial customers

A US company is developing new business models which seeks to *integrate* smaller sized energy commercial business efficiency projects *together with* DSR revenues to make the pay-backs on the energy efficiency investments ‘bankable’.

Aim is to bring cash-flow / revenue streams from both DSR and EE programmes *together*. (So, in GB terms, seeking to pull together measures like Commercial Green Deal w DSR revenue streams – and obtaining the advance of one-off upfront costs for either the DSR or EE measures from the ESCO (as they term it, ‘off balance-sheet’).

‘Combining permanent (EE) and dynamic (DSR) energy reduction assets within a property creates cost-effective synergies for added benefits…. seeks to combine knowledge of EE and Demand Response value streams to optimise the financial output and market benefits derived from these projects’.

Advantages are overcoming the upfront investment hurdle within companies. Customer pays monthly service fee and projects can be cash-flow positive from early on (presume from the monthly energy savings) ; and can earn year-end ‘DSR bonus’.

Operations : customer comfort unaffected ; customer owns the equipment at the end of the contract term. Customer signs a service contract with payment of a monthly fee termed a form of ‘performance insurance’ – which allows the initial uncertainty around savings and payback become a less critical consideration for the smaller company.

Aim is to bring together : grants available for commercial building energy efficiency ; investment in BEMS *together with* new demand-side control systems (metering, computing, software) and DSR revenue streams.

Source - Joule Assets. White Paper. Efficiency Financing and Insurance Survey. Insight into the Future of Energy Efficiency. November 2013.

4.2.4 Household customers and automated control – innovation trends and trials

Introduction

GB & Ireland trials have demonstrated trial-customers to be generally willing to respond to price signals without automation[74], but these voluntary responses took place during 'waking hours'. Household automation is seen additionally being able to support :

- Customer-response to a price-signal - irrespective of physical presence or time of day or night.

- Multiple, complex responses – e.g. different heating zones in the home, more than one appliance etc.

- Technology evolution, including better management of distributed & / or micro-generation. For example, balancing PV with automated appliances ; stored PV output in batteries which can power LED lights etc.

Automated household response could be 'static' relating to ToU- but in the longer-term it seems generally accepted that the GB system would also benefit from more 'dynamic' customer responses too. By the early 2020's, wholesale prices look likely to become significantly more wind-driven than now. We identified this possible time-scale with respect to wind-driven pricing as a potentially significant demand-side driver in Paper 9 [75]. Cost-optimising household customer load may therefore increasingly need to be more dynamic from this period onwards – if household load is to be able to become more responsive to short-run variation in wholesale prices[76]. This in turn could signify a new commercial 'pull' for household customer automation in the early 2020's. It is also important to note that 'dynamic' pricing need not be 'real-time' pricing.

This section looks at two areas where current trends and trials in household-level automated control start to point towards how, from a customer point-of-view, the future GB demand-side landscape may transform through innovation:

- **Smart appliances**
- **Smart thermostatic controls**

[74] Incentives for evening peak-avoidance (static ToU - EDF EDRP, Ireland, CLNR) ; dynamic incentive linked to simulated wind-prices - UKPN Low Carbon London.
[75] Possibly by early 2020's. Sustainability First. Paper 9. GB Electricity Demand – 2012 and 2025. Impacts of demand reduction an demand shifting on wholesale prices and carbon emissions. Results of updated Brattle Modelling. January 2014 .
[76] High wind periods – lower wholesale prices ; low-wind periods – higher wholesale prices.

4.2.5 Household Smart Appliances

The revenue streams and / or business case for commercialisation of household smart appliances in GB remain some way off [77], and therefore these appliances are not generally 'market-ready' – including in terms of their communications. This means that experience of these appliances can only be gained with the support of innovation funds. Even with such funds there remain significant technical and cost challenges associated with putting together the disparate elements of such trials[78]. Each trial has needed to :

- Define and develop the demand-side purpose of the trial (where there was one - eg peak avoidance, frequency, wind-twinning etc).
- Find appliance manufacturers open to incorporating smart controls at the manufacture stage – and which increases the cost of the appliance.
- Establish communications and control arrangements.
- Find willing customers to participate in such trials.
- Resolve any installation and operational problems (in particular communications).

[77] Other, perhaps than household level thermal storage coupled with PV – see later

[78] CLNR. Project Lessons Learned from Trial Recruitment. Report by Sustainability First. July 2013.

Table 3. A selection of smart appliance trials with automated control

GB Electricity Demand-Side : a selection of smart appliance trials with automated control – on which we found published material				
Appliances & number installed (cost-related material not readily available).	**Automated Electricity Demand-Side Service Being Trialled**	**Trial & Innovation Funding Source**	**Communications & Controller**	**Comment / Trial Results**
Heat pumps with thermal store 17	Peak avoidance for DNO. Flat tariff - w direct control by DN (up to 15 times pa – interruptions up to 4 hours – w no customer over-ride)	CLNR (LCNF)	Point-to-point	Not yet available. Completing 2014
Washing machines 151	Peak avoidance for DNO Restricted hours 16.00 – 20.00h when appliance will not work unless customer over-rides - & pays peak ToU rate (54) Flat tariff - w direct control by DN (up to 15 times pa – interruptions up to 4 hours – w no customer over-ride) (97)	CLNR (LCNF)	Point-to-point. Some initial compatibility problems for in-home comms (betw gateway & appliance) .	Indesit product developed from lab. Trialling from early 2014
Fridges & Freezers ~ 1000 fridges & freezers total (see box)	Frequency service through 'Dynamic Demand'	Npower & Open Energi CERT funded	Point-to-point Power line carrier. Some problems w in-home comms	Two phase study – 6 months from May 2010 ; 6 months to May 2012. Indesit
Quantum Storage Heaters **& Quantum Hot Water Cylinders**	Wind-related (storage, peak-avoidance, frequency)	SSEPD NINES project. Shetland (LCNF Tier 1 – thereafter	Point-to-point	Completed 2012 – now extending to more homes. Glen Dimplex Project conclusion 2016

6 homes initially - with aim of up to ~700		SHEPD Integrated Plan)		
'Off-the-shelf' Interactive Plug-In Devices **200 homes – recruitment late 2013.** 'Self-install' plug-in devices which sit between the plug and the socket for the chosen appliance(s).	Peak avoidance 'DDSR' – Domestic Demand-Side Response for distribution network	WPD ECHO (LCNF Tier 1)	Broadband (Point-to-point)	August 2013-Feb. 2015. EST & Greenlet.Strong project focus upon: customer attitudes to remote control of different household appliances ; customer response to a range of incentives for 'enduring DDSR' on a BAU basis.
Heat Pumps Smart Community Demonstration Programme. Manchester. 2-300 heat pumps. Wigan.	New project – aiming for automated heat-pump-control –to aggregate & 'trade in the electricity market'.	NEDO MoU signed March 2014 - Hitachi, BIS, DECC & Greater Manchester Combined Authority (GMCA)).		Demonstration phase - expected around Spring 2015. Hitachi
Source : Sustainability First [79]				

[79] **Table compiled from :**
CERT final report. Open Energi & KEMA. https://www.ofgem.gov.uk/ofgem-publications/58431/npow08r12-118-report-081112.pdf
CLNR Update to Ofgem. December 2013 & CLNR. Project Lessons Learned from Trial Recruitment. Report by Sustainability First. July 2013. ;
NINES LCNF close-down report to Ofgem. https://www.ofgem.gov.uk/ofgem-publications/45829/sset1003-closedown-report.pdf. October 2012 & Nines Project website - http://www.ninessmartgrid.co.uk/
WPD ECHO project - https://www.ofgem.gov.uk/ofgem-publications/83171/tier1proforma-echo.pdf
http://www.hitachi.com/New/cnews/130523a.html ; NEDO (New Energy & Industrial Organisation of Japan) http://www.nedo.go.jp/english/whatsnew_20140318.html

Table 4: A selection of smart home and community trials

GB Electricity Demand-Side : a selection of smart home and community trials – on which we found material				
Demonstration Connected Home		DEMS connected home project. Horstmann, Passiv, Indesit, EDF & De Montfort Univ. (TSB)	2007-2010	Valuable lessons – especially on communications White appliances unavailable to trial.
TSB-funded projects **August 2010 – March 2011**	'Integrating Smart Meters into Smart Homes' Strictly-speaking, not demand-side response but thirteen TSB-funded projects (£3.8m total) to 'show how smart meters can be integrated with communications technology to make homes more energy efficient, and consumers more energy aware'. The projects were required to integrate 'smart ' meters with communications technology to make a 'smart' system that will have an impact on the demand for energy in the home.			
EPSRC **TEDDI & BuildTEDDI**	EPSRC projects across 22 universities – includes some home 'automation' projects (tho not necessarily DSR-focused) : 'Transforming Energy Demand by Digital Innovation' – www.teddinet.org.uk (£22 m total). For example : **REFIT**, a project involving a smart home field trial to retrofit 20 homes, to be studied for 2-years to consider the impact on energy-use, engagement, value propositions & commercial prospects for smart home retrofit. (Loughborough, Strathclyde & UEA – www.refitsmarthomes.org). **LEEDR** – monitoring home energy use in 20 homes (gas, heat, hot-water, mains power, temperature, occupancy patterns, & 'window' activity (Loughborough). **ENLITEN** – collecting energy & related data in 200 homes to create bespoke thermal models for each house. Focus on behaviour change. (Bath, Oxford) **E-ViZ** – a project focused on 'visualisation' as a catalyst for energy demand reduction & behaviour change. (Plymouth, Bath, Birmingham, Newcastle). **DANCER** – wireless sensor networks designed to intelligently reduce individual energy use being tested in a small number of homes (Essex, London South Bank).			
Source : Sustainability First.				

Conclusion : smart appliances in the GB household sector

So far, GB demand-side trials of automated smart appliances been relatively small scale, with a largely technical focus, designed mainly to demonstrate 'proof of concept'. That is, to demonstrate that it is technically feasible for households to provide automated demand-side response via a number of different appliance-types to the electricity system, including : frequency services ; static peak-avoidance ; and wind-matching / load-building (storage). In this narrow sense, the trials have broadly succeeded.

Nevertheless, other technical and commercial considerations come into play - as well as the likely 'customer acceptability' of automated appliances [80] - and in this sense deployment at scale of smart appliances for household DSR still seems some way off.

In particular, GB smart appliance trials have not so far included much by way of cost-benefit evaluation of the DSR contribution which the trialled smart appliances may eventually make to the GB electricity system. **A clearer view as to which automated household appliances might eventually become best-placed to provide which services to the GB electricity system – and also where greatest value might lie for households in providing those services – may be needed to help appliance manufacturers gain a better insight into how their 'development effort' on smart appliances for the GB market may best be applied.**

In chapter 5, we discuss experience of storage heaters and hot-water cylinders – and the potential benefits of thermal storage - in particular the SSEPD NINES project in Shetland.

Consumer views on automated demand-side control, in so far as these are known, are touched on in chapter 6.

[80] See chapter 6 for more on customer attitudes to automation

GB Trial of Household Fridges & Freezers to provide Frequency Response - Npower & Open Energi[1] (Indesit appliances).

This trial, reported by nPower as 'Europe's largest field trial of smart grid home appliances' was funded under CERT (Carbon Emissions Reduction Target. 2009 – 11). The trial had 2 key aims :

- A technical demonstration that household fridges and freezers – (or other household appliances with a 'storage' capability such as electric heaters, hot-water systems or air-conditioners) - are able to provide 'frequency responsive' load to the system operator : in this case, via Open Energi's patented 'dynamic demand' technology embedded in the appliance electronic control-board. When system frequency rises, 'available' appliances are synchronised to switched on to help compensate. When system frequency drops, 'available' appliances are synchronised to switch off.
- To demonstrate a related carbon saving calculation (because in principle fossil fuel could be saved by displacing by fossil plant held 'spinning reserve') as the project was funded via CERT.

The trial ran from 2010 and concluded in March 2012. It involved 2 phases, installing ~ 1000 appliances of four different types in total.

Smart fridge type	Phase 1. May – October 2010		Phase 2. January – May 2012	
	Installed	Monitored	Installed	Monitored
Combi Fridge Freezer w defrost	300	280	-	-
Static Combi Fridge Freezer w no defrost	-	-	390	134
Upright Freezer	-	-	180	81
Table Top	-	-	80	-

Appliances were installed with regard to day-time occupancy patterns and affluence. For Phase 1, installations were mostly in the homes of npower staff and social housing residents. For Phase 2, more regard was given to socio-demographics: likely fridge usage patterns, number of occupants and one-third benefit recipients.

Delays in appliance roll-out made for : 'notable difficulties in obtaining customer engagement in the second phase of the trial for install of home monitoring technology'. This was because customer contact came many months after the appliance roll-out – requiring a project extension.

Trial outcome : This was largely a technical trial - & not a cost-benefit analysis of how frequency responsive fridges might serve the GB electricity system.

The report to Ofgem indicates that on a number of occasions when a rapid system frequency change took place (including during televising of the 2010 World Cup), that the fridges responded as designed : namely as frequency rose, the fridge motor switched on (for up to 4 minutes) : as frequency dipped the motor switched off (for up to 8 minutes). The external ambient temperature (rather than variation in patterns of fridge usage) was identified as the main factor to determine fridge 'availability' for switching (ie where it was in its cooling cycle). A number problems were encountered with the set-up for the in-home communications, including the monitor.

The technical parameters were designed so that fridge owners would notice no difference in their appliance performance, so that food stayed cold or frozen within user-defined set-points.The report to Ofgem does not offer any insight into what the 1000 trial customers felt about their fridge being remotely controlled, nor their experience of helping to provide system frequency services to the system operator (other than the lack of engagement from Phase 2 participants in having monitoring equipment installed).

4.2.6 Smart Thermostatic Controls

Smart thermostatic control of heating and hot-water is already both established and commercialised.

Smart thermostatic controls may offer some or all of :

- 'Sensing' of external temperature & adjustment of internal temperature.
- 'Intelligent' remote control of main in-home thermostat – run-time, temperature .
- 'Intelligent' control of *zonal* thermostats in the home.
- Householder can 'remotely' adjust temperature and / or switch heating on-off.
- Use of movement sensor(s) to detect whether home occupied.
- Use of mobile phone mapping functions to detect customer proximity to their home to automatically switch-on heating.
- 'Bundling' of DSR, energy efficiency and appliance performance monitoring (California example).

Strictly speaking, in GB smart thermostatic controls have yet to be applied to electricity demand-side actions – but **instead are largely focused on smart home heating controls – in particular for gas boilers** (but not just). Given the dominance of gas home heating in GB – both in terms of customer bills, and in terms of carbon emissions, a GB focus on household gas efficiency seems appropriate[81].

However, looking to a future for GB household DSR it is helpful to understand how programmeable thermostats are already in use for DSR purposes in geographies where there are already substantial electric cooling, heating or other large and flexible electric household loads.

In the USA and elsewhere, a variety of smart programmeable thermostats have been in use for DSR purposes for some time, entailing remote-control of air-conditioners and heat – often in conjunction with a utility programme for curbing critical summer cooling peaks. There seem no significant technical or commercial obstacles to GB deployment of thermostatic control for DSR for electric heat (or water heaters) – other than our relative lack of large controllable domestic loads.

In the US and Germany thermostatic controls are understood to be suited to self-install by the customer. In the UK, an installer may presently be needed to wire-in the new smart thermostat in place of the existing room thermostat[82], and this adds to the total cost.

[81] In GB, a variety of smart thermostatic controls designed for household boiler use are rapidly entering the market under a number of brands, including, inter al BG's Hive, Tado, LightwaveRF, NEST, Evohome.

[82] Albeit some are marketed as 'self-install'.

US Example : Smart Thermostat Used for Household Electricity DSR (this product not currently launched in UK (April 2014)).

The NEST 'Learning Thermostat' retails direct to US customers at $249 (£150) on a self-install basis. Also, some 'partner utilities' offer specific energy plan arrangements which include a NEST thermostat (electricity & gas) either for general energy savings (on a basis that air conditioning can use around half-the energy used in a home) - or expressly for avoided summer peak[83].

For avoided summer air-conditioning peak : NEST allows a home to be automatically pre-cooled for an hour in the early afternoon, followed by automatic control and adjustment of the thermostat for the next 4 hours to maintain a target temperature of around 25 degrees C. The control can differentiate by whether a customer is at home (and so perhaps may need a lower temperature maintained over the full 4 hours). Customers are told they can expect no more than three events on three consecutive days – and around a maximum of twelve events per year (17 in Austin, Texas). Customers are notified the day before (via the NEST, a NEST app and web). There may be no warning in extreme events.

Afterwards, customers can see on their display that there was an 'event' – and how the automated temperature control had (on average) compared to 'normal' days (they also receive information in a monthly NEST energy report).

Customers can over-ride the temperature control – and see a message to indicate that this action may impact their 'reward'. After the DSR event, the controls revert to their previous settings.

Participating energy companies pay 'rewards' in a variety of ways : a flat fee per cooling / heating season ; payment or rebate for NEST 'bundled' into service agreement ; payment per event (calculated in terms of 'difference' against a 'normal' consumption benchmark (e.g. consumption on three highest preceding business days out of previous five). So, payment is attributed to how much electricity is calculated to be saved by the air-conditioner not running. Assumption is that electricity used by other appliances not controlled by the NEST remains the same – wet appliances, pool-pump etc. (NEST website indicates a rebate payment of US $ 20-60 depending on utility partner).

NEST website account of two consecutive 'dynamic peak' events in summer 2013

In Austin, Texas on 27 June 2013 the temperature was 38^{o}C-plus (100^{o}F). NEST adjusted thermostats for 'a couple of thousand' customers – and air- conditioner 'run-time' was cut, on average, by 56%. On their website NEST claim :

> 'each thermostat calculated the best way to shift energy and keep their individual home comfortable. The algorithm for every home was unique, based on that family's schedule, the temperatures they liked, if they were home or away, and how drafty their house was. The results were impressive : for two hours that afternoon, as outside temperatures soared to 102^{o}F, AC runtime was cut in half. That's compared to how much energy we calculate people would have used that afternoon, based on their schedules and the weather. NEST pre-cooled many of the homes before the 'rush-hour' then let temperatures drift up less than 1.6^{o}F on average. The result ? Almost everyone stuck with it – only 10% of people adjusted the temperature at all during the 'rush hour'. The next day ? It happened again. Temperatures climbed even higher and there was another 'energy rush hour'. This time it was 106^{o}F outside and Rush Hour Rewards cut AC use by an average of 49% during the rush hour. Only 12% of Nesters adjusted the temperatures NEST set'.

Participating Austin Energy customers were offered a one-off seasonal flat fee payment ('Rush Hour Rewards') of US $85 per NEST device - in return for allowing the temperature in their homes to be remotely controlled by the smart thermostat to reduce summer cooling peak. Customer comments on the web-site suggest that they were content.

NEST say that they plan to add features like time-of-use energy management, instant peak saving, and 'energy budgeting'. The NEST website also explains that data processing for 'Seasonal Savings' and 'Rush Hour Rewards' are powered by 'Auto-Tune' – and that :'Auto-Tune needs significant memory, storage and processing power - all maintained in the cloud. Takes all of your Nest Thermostat's knowledge into account before it makes even a small change to your schedule. That includes your temperature preferences, schedule, occupancy info and weather - everything your Nest Thermostat has learned about you plus real-time data about the temperature. Maintaining all this data is expensive, and by partnering with energy providers we don't have to pass the cost on to our customers'.

On 13 January 2014, Google acquired NEST. Arguably, their new parent may offer NEST the fire-power to develop the kind of business applications described above (apps, upgrades, data-processing etc)[84].

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[84] FT. 14 January 2014. Hard copy p.19. 'Google in $3.2bn Nest deal'.

4.3 What are the main technology issues relating to automated demand-side control for GB households ?

At least four major technology areas still seem in need of further development before we are likely to see automated demand-side control developing successfully at scale at the household level in GB:

- **Communication into the home of a price** (or other) **trigger** - coupled to a command to switch an appliance on or off (up or down).
- **Validation of household demand-side actions** - both for market-wide settlement purposes and for individual customer billing
- **Electricity system security** – including with respect to remotely-controlled 'smart appliances'.
- **Technical standards**.

4.3.1 Current approaches to communications for GB household automated control

Below we briefly describe current and expected approaches to wireless communication and automated control for household demand-side control programmes in GB.

No external signal :

- **Appliances with in-built timers / delay function -** allow the user manually to pre-set a programme and / or time-delay. Example wet-appliances : washing machines, dishwashers. Other than Economy 7, there is assumed to be very little present DSR customer-activity (because so few ToU retail tariffs). However, with a ToU tariff, customers may start to make use of appliance-timers etc – so, in effect 'self-automate'.

One way communication :

- **Radio Teleswitch** (RTS) **–** The Radio-teleswitch provides a long-established *one-way communication system for remote activation of meter switches* – to control over-night electrical charging of some Economy 7 & 10 storage-heater and hot water load[85]. Around 2 million GB homes still have a meter with a radio-teleswitch which can control (& meter) the on-off electrical charge times of storage heaters (& hot water cylinders), commonly wired into a separate electrical circuit. ~500,000 of these meters (mainly now in Scotland) are 'dynamically' switched (the remainder are switched at static times). The RTS sends a signal to the meter - via three long-wave radio transmitters, co-ordinated via

[85] By no means all off-peak Economy 7 storage heaters & hot water cylinders are controlled by the RTS : many are controlled by integral time-clocks.

a central communications hub. The Radio-teleswitch may not be maintained beyond 2017, including its role in randomised 'staggering' of the meter switching[86]. Notably, the present RTS offers no future possibility for new or for different automation applications : it is understood that its current capability cannot be upgraded to support *new* forms of tele-switched services[87].

Two way wireless communication :

- **'Point-to-point' wirelessly-connected equipment or appliances** (M2M – machine to machine)**.** These may communicate either via a mobile signal direct to the appliance (eg GPRS), or, increasingly, via a broad-band internet connection – which thereafter communicates wirelessly in-home (e.g by Bluetooth, Wifi, power line comms). This might be direct to the appliance to be controlled, or, to an in-home controller with connectivity to the appliance via compatible in-home wireless communications. The appliance can then turn on and off in response to a wireless command. The command may relate to price - or to another trigger / signal (e.g. of 'system-stress'). The appliance (or controller) can also transmit data back about its operation, *via the internet*. M2M control is a well-established form of communication for DSR services provided by customers in the I&C sector.

  As noted, the most rapidly deploying commercial application of 'point-to-point' heating control in the household sector is the programmeable thermostat – both internationally, and in GB.

  GB smart appliance trials to date have shown that appliance-level point-to-point control with two-way communications is feasible for delivery of household DSR services. Notably however, GB trials to date have dealt with a number of technical wireless communications challenges (i.e. sustained 'connectivity' between external communications, in-home controllers and appliances) – and the equipment, software development, dedicated communications and installation – are potentially still comparatively high-cost per-unit per-household (plus household 'smart' appliances (fridges, wet appliances) are not yet market-ready at scale[88].

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[86] For system stability reasons.

All SMETS compliant meters will instead incorporate a capability for 'randomised' switching to avoid system instability from universal / standard switching times. However, switching will not be 'centralised', as facilitated now by the RTS.

[87] Elexon. Dynamic Switching. Way Forward. February 2013.
Ofgem 133/13. The state of the market for customers with dynamically tele-switched meters. July 2013.
Also on RTS : 'The Load Management Functions that must be delivered by the smart metering system'. S.D Wilson, D.C Brogden, B. Hopkins (paper by EA Technology & SSE). 2013.

[88] Smart / programmeable thermostats excepted.

4.3.2 Smart meter communications approaches for in-home automated appliance control

Via the smart meter arrangements there are two approaches (in broad terms) to the communications set-up for enabling commands to be sent for automated load-control of home appliances[89]. See Annex 2 of this paper for some helpful DECC diagrams which illustrate these.

(1) Via Auxiliary Load Control Switches (ALCS).

A **licensed supplier** is able to send specific **'critical commands'** to an Auxiliary Load Control Switch via the DCC - for example, to switch a particular load either on or off in a customer's home[90].

Auxiliary Load Control Switches can either be integrated into the meter - or can be separately connected via the Smart Meter Home Area Network (HCALCS – see below). These switches will be capable of responding either to (1) direct commands to 'change state' of the switch or (2) to 'change state' based on a switching-calendar in the meter. Communication is *two-way* with the DCC, allowing 'validation' of the demand-side actions. (A supplier who sends the command will receive a confirmation that the command has been received)[91] .

Of the sixteen planned ports on the Smart Meter Communications Hub, up to seven ports will be allotted to connecting so-called Type 1 'trusted devices'[92] (so, perhaps an EV charger, a heat-pump, a hot water tank, a group of storage heaters). SMETS 2 meters can support 'switching calendars' for up to five auxiliary load control switches.

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[89] SMETS 2 meter functionality will also support other forms of DSR, for example through enabling tariffs (ToU, Block, Dynamic) ; load limiting & maximum demand registers (i.e. for capacity-related DSR) ; & randomisation.

[90] **For security reasons, only a licensed supplier is able to send 'critical commands'**. In due course, distribution networks may be also be permitted to send 'critical commands' to a customer's ALCS via the DCC – but not at first – and **any such change would entail a formal modification to the Smart Energy Code.** (Smart Metering Implementation Programme. Consultation on the Process to finalise the GB Companion Specification (Feb 2014) & DCC User Gateway Interface Specification (Jan 2014). Also, discussion of draft demand-side 'use-cases' in DECC/Ofgem Smart Grid Forum WS6 (Jan-March 2014).

[91] Or, that the switching-table has been updated with a new schedule

[92] Type 1 devices are registered **by the supplier** with the DCC as a 'Trusted Device'. 'Type 1' *does not describe the type of appliance* – but rather describes the 'trusted' pairing arrangements between the supplier & the ALCS – and registration of that device with the DCC inventory of 'trusted devices' (Type 1).

As at March 2014, up to seven ports for Type 1 devices (Type 1 devices may be HCALCS and / or (PPMIDs) Pre-Pay Interface Devices) as per smart meter communications hub technical specification. The auxiliary load control switching calendar must support ***up to five*** auxiliary load control switches (the limiting factor in all meters is the memory space for the switching calendar). Each switch could control a group of appliances (e.g. several storage heaters).

There are two different ways in which Auxiliary Load Control Switches will be deployed with SMETS 2 meters [93] :

- **A 'variant' SMETS 2 smart meter –** where Auxiliary Load Control Switches (ALCS) are **integrated** into the meter. Variant meters are chiefly aimed at existing Economy 7 homes where electric storage heaters (& hot water) are already wired and metered via a stand-alone electrical circuit. During smart meter roll-out, installation of variant meters to existing Economy 7 customers will enable their storage & immersion heaters to continue to be separately switched on & off over-night - and metered – just as now [94].

- **Smart Meter Home Area Network-Connected Auxiliary Load Control Switches (HCALCS) –** these switches (relays) may be installed either at smart meter roll-out, or - more likely - installed & connected *after* initial roll-out in order for specific appliances to be automatically controlled. As noted, two-way communication for HCALCS will be via up to five dedicated ports on the smart meter communications hub. 'Type 1'devices will be registered *by a supplier* with the DCC as a 'trusted device' - and securely paired by the supplier with the smart metering system - in conjunction with a load-management arrangement / tariff.

(2) **Via the Customer's Home Area Network - & Consumer Access Devices (CADs).**

For willing customers, the CAD route to home-automation is also expected to allow either customers or third parties - DNOs, aggregators, ESCOs - to under-take actions to control a consumer's home appliances *from the consumer side of the Home Area Network* .

In principle, CADS could control any appliance in the home (e.g. a heat-pump, storage heaters, hot-water cylinders, washing machine, fridge, smart thermostatic controls etc).

Third parties (including those who are Smart Energy Code signatories) cannot send 'critical commands' (e.g. on / off) via the DCC to the five Auxiliary Load Control Switches – nor, as such, send a 'critical command' via the DCC to an appliance on the customer side of the home area network.

Instead, with a customer's agreement, the intention is for third parties to be able to offer 'energy management' solutions to customers (or, for customers to manage this themselves). At the simplest level, such a system could just be a small box which

[93] Smart Metering Equipment Technical Specifications.

[94] Variant meters cost more than a standard SMETS 2 meter (additional cost understood to be equivalent to non-smart Economy 7 meters today). So, initially, variant meters are most likely to be targeted at existing Economy 7 customers. For the future, 'variant' meters - with **integral** Auxiliary Load Control Switches - might also be installed in new-build homes (or on major re-furbishment projects), where heating is on a stand-alone electrical circuit.

forwards data via a customer's existing wi-fi router, to be stored and / or analysed in the 'cloud'. At a far more complex level, such an energy management system might control a range of different appliances in the home by aggregating and analysing data from various sensors. In turn, this could allow commands to be sent via broadband to turn appliances on / off. Equally, commands could be automatically generated by the energy management system, based on the information received from the sensors. Rules or algorithms driving commands could be updated by the service provider, or by the customer.

Where an energy management system includes a compatible zigbee interface, then a consumer or a third party would be able to connect that system to the Smart Meter Home Area Network (SMHAN)[95]. A device capable of being connected to the SMHAN is known as a Consumer Access Device (CAD).

With customer consent, once a CAD is connected to the SMHAN, an energy management system could then make use of customer information held on the meter (i.e. a customer's price and / or usage information). This meter data could then provide additional inputs to the rules or algorithms driving the automated appliance control. For example, the CAD might be pre-programmed with an algorithm which might state 'when price exceeds x pence / kWh, then switch-off this appliance'. So, a control unit, or an appliance with a built-in controller, could use the prices (current, future) received from the meter system to switch a customer's appliance(s) on or off ; up or down**.** The customer may have over-ride : either directly via an in-home controller ; or, by sending commands via broadband to a remote energy management system.

Validation of the customer's demand-side action could be communicated over the customer's internet connection (and not via the DCC). For example, perhaps where a *third party* may have an arrangement with a household customer to provide peak-avoidance services to the distribution networks, or to provide balancing services to the system operator.

[95] Customers and / or registered DCC-users (i.e. signatories to the Smart Energy Code) can create an interface with the smart meter communications hub for one or more CADs by sending a command which contains the credentials of the CAD to the smart metering system via the DCC (i.e. to 'pair' a CAD **on the consumer side** of the smart meter communications hub, via a secure 'key code'). In turn, this will allow the CAD to receive the 'read-only' price and consumption data, sent from the meter. In turn, this will allow a customer and / or registered DCC-users (or, where agreed, perhaps other parties) **to make use of that price and consumption data in support of automated actions for in-home appliance control** e.g. to generate 'third-party' commands to control an appliance *from the consumer side* of the Home Area Network (e.g. by use of a time-related, price-related or other signal).

Should the customer wish, this demand-side activity could either be (1) with the knowledge and / or agreement of their supplier - or (2) wholly independent of their supplier.

Also, a supplier could come to a bilateral arrangement with a third party for the supplier to activate control via the critical commands which the supplier can send to Auxiliary Load Control Switches / trusted Type 1 Devices (HCALCS / PPMIDs) i.e. the supplier could activate control *on behalf of* a DNO or an aggregator)[96].

DCC Charges : Fixed & 'Explicit'

DCC will charge its users fixed and / or 'Explicit Charges'. Users of DCC who are not licensed energy suppliers or networks – and **only** make use of DCC CAD-related services – will **not** be subject to fixed charges – but may incur Explicit Charges. Inter al, DCC 'Explicit Charges' may include : charges for volume of messages sent between smart metering systems, the DCC user-gateway and service-users ; charges for connection to the DCC user-gateway ; charges for testing ; charges for support services [97].

On the face of it, **volume-related charges** for messages sent between the smart meter system, the DCC and service users may tend to work in support of simple static tariffs & commands – rather than in support of constantly changing dynamic prices or many *variable* commands (albeit dynamic 'critical peak' commands for the capacity market - a few times a year – ought not to cost very much). Also, we can perhaps assume that if significant demand-side value was available in the wholesale or balancing markets for a supplier from highly dynamic tariff approaches (eg say for 'wind-matching), then volume-related communications costs may not necessarily act as a deterrent.

At this early stage, it is premature to judge how DCC charges may impact market actor approaches to load control and retail tariff offers.

[96] DECC / Ofgem Smart Grid Forum WS6 is currently discussing hypothetical 'use-cases' of this kind (March 2014).

[97] https://www.ofgem.gov.uk/ofgem-publications/85485/draftchargingstatementforry201415.pdf and http://www.smartdcc.co.uk/media/5574/indicative_budgets_for_ry_2015_16_and_ry_2016_17_-_8_january_2014_-_issue_1_0_.pdf

4.3.3 Conclusion on GB Household DSR approach to communications

In developing this paper, many of those with whom we spoke (a mix of large suppliers, networks, new product manufacturers and demand-side service 'innovators'), seemed broadly to favour the smart meter communications approaches for automated household load control (be these the auxiliary load control switch arrangements and / or the CAD arrangements).

This support was due largely to the potential seen (in broad terms) of a common 'in-home' platform capable of receiving / being informed by smart meter data – and from which base it was expected that home appliance automation (and other smart home services) would in due course be able to develop and grow.

From a third party view-point (ie for all actors other than suppliers) with the potential for a CAD to receive a customer's half-hourly price data plus customers' consumption data (potentially at ten-second resolution) on a read-only basis from the meter, the CAD arrangements were expected to support better long-run technical and commercial co-ordination of home automation between market actors, including, perhaps, for certain forms of DSR validation and related billing.

Considerable time and effort has been devoted to developing approaches to smart meter communications – one aim being to enable GB home-automation to develop on a secure and generally interoperable basis. The approach adopted will enable (1) suppliers to switch selected appliances securely by sending 'critical commands' to these appliances via auxiliary load control switches (either on their own behalf or on behalf of others) – and in addition - (2) for third-parties also (inter al) to have the potential to control appliances in the home via Consumer Access Devices[98].

Both the technical capabilities and commercial arrangements for automated load control of appliances by suppliers via the smart meter arrangements (auxiliary load control switches, HCALCS etc) have been carefully specified and regulated. Similarly, the interface with CADs, the data available to CADs, and the secure 'joining' process for CADs has also been carefully specified. CADS may therefore also be expected to support the technical and commercial development of a future GB household demand-side – including development of automated and other 'smart' home services and markets[99].

In discussion, it was generally felt that making use of the smart meter-connected communications infrastructure for home automation would offer some long-run benefits. These were thought to include : making the most of investment in the smart meter

[98] A very helpful set of DECC slides were presented to the DECC / Ofgem Smart Grid Forum Work Stream 6 on **18 March 2014**, which set out the expected arrangements on the smart meter communications infrastructure for home automation and the CAD arrangements. The slides will become available here : https://www.ofgem.gov.uk/electricity/distribution-networks/forums-seminars-and-working-groups/decc-ofgem-smart-grid-forum/work-stream-six.

[99] BEAMA is currently developing a common high-level communications protocol for the CAD. There is no current intention to develop a common GB standard for home automation – which would be a very costly and resource-intensive process.

infrastructure (for which all consumers will anyway pay) ; potential improved 'visibility' between market actors of demand-side actions taken by households ; the potential for greater overall cost-efficiency for development of the GB household demand-side ; and, possibly, from a customer point of view greater fairness (e.g. by perhaps helping to avoid needless 'lock-in' to one-off home load-management arrangements which might otherwise be unduly provider- or product- specific).

In discussion, there were nonetheless some outstanding queries around the detail of how the communications arrangements for household-level automated DSR may work in practice : be that via auxiliary load control switches or via the CAD arrangements.

On CADs, one area for clarity is around the likely detail and timetable for finalising a common high-level communications specification[100]. Some companies are already developing and manufacturing CADS, but further clarification may be helpful, for example, in allowing developers of innovative customer-facing DSR products and services to understand more about the future supply chain. Two questions might be: when might development of a common high level communications specification for CADs expect to successfully complete ; and, how far might development and commercialisation of compatible CAD products be expected to be in tandem with the smart meter roll out (so, from 2015 onwards) - or largely follow it in terms of innovative demand-side product development (perhaps from the 2020's onwards ?). DECC is understood to be producing a consultation on consumer access to data and data access services in the coming months, and this should be helpful.

Such clarifications will also help those who may see potential for an 'alternative future' via a continued growth in separate 'point-to-point' appliance arrangements for household automated demand-side control, potentially separate from the smart meter communications in-home infrastructure.

[100] The communications specification for CADS will be Zigbee SEP 1.2 – with features being defined in the GB Companion Specification, due to be finalised in 2014. The proposed process for completing this can be found at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277923/SMIP_Finalising_the_GBCS_Consultation.pdf

4.3.4 Other key technology issues

As noted at the beginning of this section, other important technical issues need resolving before we will see automated household demand response at scale, but we do not discuss these in detail in this paper. Not least, satisfactory development of the arrangements for the smart meter system, in tandem with the arrangements for consumer access devices, are expected to some large extent to help clarify and address these areas too :

- **Validation –** in-home automated load in receipt of a 'payment' or reward for flexible services will need some form of 'validation' that the demand-side actions indeed took place. This may involve validation (1) for the market-actor to whom the flexibility service was provided – and (2) for the market in general (to understand any associated costs, such as possible imbalance).

    - With customer consent, half-hourly household-level usage data will be available for demand-side verification purposes – either via the smart meter system and / or via the CAD. (This will be so, regardless of whether the market is also eventually settled on a half-hourly basis).

    - Some household-level DSR services (for example, some Balancing services), might require verification at intervals far more frequent than half-hourly (depending on the nature of the demand-side service provided) [101] . In such cases, meter data could become available to a CAD from the smart meter system at up to ten-second intervals. Where useful for verification purposes, such data could be communicated beyond the home for verification purposes via the internet to the relevant actors.

    - In the case of automated demand-side services delivered by smart appliances which may be controlled on a 'point-to-point' basis, there may be no direct interface with the smart meter system (so, no interface via the smart meter or via a CAD). In such cases, there would be no access to household-level meter data - and an alternative approach to verification for point-to-point controlled appliances may be needed.

- **Electricity metering system and cyber security** - the 'barrier' and interface arrangements being designed between the communications infrastructure for the smart meter system - and CADs (consumer access devices) – have largely been designed to ensure meter integrity and data security. Security considerations have been a key driver in initially allowing only licensed suppliers to connect 'trusted devices' (Type 1 appliances) and to issue direct 'critical commands' via auxiliary load-control switches. Not discussed in this paper, but from a customer viewpoint, the question of cyber security in terms of those smart appliances and home products which are internet-connected will need to be

[101] Depending on the type of demand-side service provided – eg whether 'static' day-in-day-out or 'dynamic. Some services for example for Balancing (Frequency, STOR) would require validation at much more frequent metering resolution.

addressed before consumer confidence in the 'internet of things' is likely to develop at scale[102].

- **Technical standards –** GB demand-side communications approaches and new DSR-enabled products and equipment will conform to EU and international technical standards. This is important for the supply-chain om terms of bringing down costs through volume and scale – and also for cyber-security considerations. GB innovation initiatives will need to take account of EU and international standardisation efforts [103].

[102] Metering International. 20 January 2014. 'Internet of Things cyberattack: Fridge and TVs hacked'. Item by Kim Jansen. Also, picked up as front page story in Metro newspaper. 'A fridge full of SPAM'. 21 January 2014.

Also, https://blog.kaspersky.com/beware-the-thingbot/ (22 January 2014).

[103] IEC Technical Committee 57 (International Electro-technical Commission) – develops standards for information exchange for power systems – and other related systems – including energy management systems. For example : *In draft* – IEC TC 57 TR62746-2 System Interface between Customer Energy Manager and Power Management System – Part 2: Use Cases and Requirements.

4.4 What are the main commercial issues relating to automated demand-side control ?

Commercial conditions for a functioning GB I&C electricity demand-side market are increasingly 'nearly there'. As a result, more 'customer pull' than now can perhaps be expected to develop.

I&C Sector - Commercial Conditions for Demand-Side

I&C customers are increasingly better placed to assess whether the likely benefits from different GB demand-side schemes will outweigh the costs of their participation. Assuming that a customer business case is there, most ingredients (technical & commercial) are already in place for I&C customer demand-side activity to grow over the next five years. These include:

- **Identifiable, accessible and predictable revenue streams –** i.e. from Balancing, DSBR, Capacity Market, (TRIAD), Network Fault Management etc. Such revenues are key in commercialising customer demand-side services to offset the **costs of up-front investment in the communications and control equipment needed for automated load-control** (unless paybacks are very short) **– including the cost of any on-going upgrades and equipment maintenance.**
- **A relatively small pool of I&C customers with larger loads –** bigger individual rewards ; likely participants relatively easy to identify ; able to offer certain types of flexible demand-side service.
- **Suitable meters with half-hourly (or higher) resolution to produce adequate meter data to validate** that the agreed demand-side actions took place.
- **Half hourly settlement** (& soon for LP 5-8) to enable accurate customer billing against actual half-hourly usage[104] .

These conditions do not presently exist for automated demand-side control for the GB household sector. In discussion there was a clear wish for a better understanding for some of the likely *time-lines & dependencies* which might create similar commercial conditions for automated load control for the household sector.

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[104] Where half-hourly settlement is sufficient to validate the service provided

As well as smart meters, conditions likely to foster greater commercial development of automated household load are likely to be some (or all) of:

- Flexible household load (& at scale, what is that likely to be?)
- Controllable load
- Retail tariffs to incentivise flexibility.
- Two way communications for validation
- Data management capability – i.e for validation (household level, & possibly appliance level).
- Individual-level half-hourly settlement (perhaps for some 'dynamic' automated DSM)
- Consumers – 'engaged' / willing ; appropriate safeguards
- Market actor business case – and the likely different demand-side revenue streams - otherwise no 'value proposition' to offer customers.

DECC's Smart Meter Implementation Programme, Ofgem's Smarter Markets Programme, and the detailed work of the DECC / Ofgem Smart Grid Forum Work Stream 6 are each addressing a great many of these topics – and the different 'strands' may be expected to 'come-together' at a practical level in the early 2020's. An important initial and welcome step is the development by Ofgem of its proposed DSR Framework to formalise the interactions and practices among different market actors in the value chain who use DSR, to support industry parties in being confident that investment in demand-side response is justified[105].

As a result of the discussion which informed this paper, in this section we focus largely on the last bullet point above regarding the **market actor business case**. In our discussions, this was felt to be core in terms of improving understanding of how commercial development of a GB automated household demand-side and greater 'customer pull' may in practice develop over the coming decade.

[105] Ofgem. 'Creating the right environment for demand-side response : next steps'. 16 December 2013

4.4.1 Household Automated Control - Commercial, Policy and Regulatory Uncertainty

We have seen that 'smart' thermostatic controls are both market-ready and are being commercially deployed – (albeit so far in the GB household sector, not for DSR purposes).

Even so, from a commercial perspective, GB a household-level electricity demand-side at scale **via automated control** still seems some way off.

Considerable commercial uncertainty attaches to both the likely costs and potential benefits of automated household customer participation. In our discussions for this paper it was widely assumed that the likely costs will continue to outweigh the benefits for some time to come.

The uncertainties around the costs and benefits for the GB household automated demand-side stem from a complex mix of commercial, regulatory and policy questions :

- **The market actor business case and value-proposition remain unclear** – both in terms of peak-avoidance and / or longer-term with respect to 'wind-matching'.
    - **Pre-2020, only limited cost-savings for market actors may be available from demand-side actions at the individual household-level** (both wholesale market savings and network savings)[106]. As a result, there is not yet a clear commercial driver for suppliers (other than for reasons of 'market advantage') or for networks (unless at network 'hotspots') to invest in and to develop demand-side retail customer offers involving automated household demand response at scale.
    - **In the 2020's, a far better understanding is needed of the potential impacts of wind upon wholesale prices** - and how automated household DSR designed to broadly 'wind-match' might in practice deliver - before a business case for some form of automated 'wind matching' by households is likely to be demonstrated[107]. This includes the overall 'value proposition' for the supplier – as well as the reward, feasibility and convenience for the customer[108].

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[106] Frontier Economics. Domestic and SME tariff development for the Customer-Led Network Revolution. Report for Northern Powergrid. June 2012.

[107] SF Paper 9 – GB Electricity Demand – 2012 & 2025. Impacts of demand reduction and demand shifting on wholesale prices and carbon emissions. Results of Brattle modelling. January 2014.
Electricity System Analysis – future system benefits from selected DSR scenarios. Redpoint Energy, Baringa & Element Energy paper for DECC. August 2012 - modelled customer benefit from automated load control in 2030.

[108] In chapter 5, we look at how thermal storage (heat, hot water) could potentially play a role in wind-matching.

- **GB electricity market arrangements need to develop before automated or dynamic household DSR could happen as scale –** i.e. both cost and big institutional change needed to enable scale household participation (smart meters, settlement reform, aggregation, transactions among parties, customer relations & customer billing).

- **Widespread application of automated control is generally expected to follow rather than precede the smart meter roll-out** (2015 onwards)[109] – because expectation is that both smart meters plus Consumer Access Devices needed.

- **Flexible sources of readily-controllable household electrical load – are not yet widely deployed at scale in GB** (electric heat, EVs) or are not yet technically or market-ready (higher unit costs of 'wirelessly connectable' fridges & washing machines).

4.4.2 Developing a better understanding of the likely costs and benefits of automated household control

Despite the trials noted in the Table earlier in this chapter, there is still an imperfect understanding of the full picture on costs and benefits for automated household demand-side participation at scale**.** In particular, as to how costs and benefits may fall to each of suppliers, networks, aggregators and household customers. We discussed some of these demand-side cost and benefit issues in Paper 8. [110]

For the purposes of this paper we are chiefly concerned with how the specific costs and benefits of **automated** household control, need to be far better understood before a market in automated household services is likely to develop at scale. The boxes below outline some areas in need of a better understanding on both the cost and the benefit sides.

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[109] Smart meters will record half-hourly data which will be adequate for billing customers who participate in voluntary or automated 'static' ToU approaches to demand response – be this on a 'voluntary' or 'automated'basis. **Dynamic approaches to demand-response** would most likely require both half-hourly data for customer billing, *plus* half-hourly settlement for accurate allocation of cross-industry charges – including if the dynamic response was automated.

[110] SF Paper 8 : 'Electricity demand and household consumer issues'.

Household Automated DSR : Possible Costs

Household demand-side automation can be expected to build on the back of the smart meter roll-out – (the costs of which customers will meet via their retail bills[111] payable to suppliers). The following costs are already factored into the smart meter roll-out : smart-meters and the smart meter communications hub : DCC set-up, basic DCC operation and roll-out of a smart meter communications network ; initial offer of an in-home display.

Communications costs for home automation – DCC approach to charges (Fixed & 'Explicit'). Suppliers & Distribution Networks will pay a fixed charge and / or 'Explicit' Charges for other services. Other market actors will pay Explicit Charges for certain services (e.g. volume-related charges, a connection charge etc). Third parties will also need access to an existing (or dedicated) internet connection.

'Additional' costs for automated household control

Some potential 'additional' costs which may be incurred in development of automated household control at scale – and not already factored into smart meter roll-out costs - seem to be :

- Retrofit of Auxiliary Load Control Switches
- Development costs of CADs and / or controllable appliances (e.g. wet appliances, heat pumps, thermal storage heaters and hot-water cylinders, EV chargers etc) [112].
- Cost of additional controllers and / or any sensors for 'control' purposes (other than those already embedded in a smart appliance).
- Install costs for ALCS, CADs, controllers, sensors etc (where these are not 'self-install' or embedded in an appliance).
- Computing power to process large data volumes for 'intelligent' control - and the technical and commercial capability to deploy that information 'intelligently'. Maintaining & updating associated software.
- Costs of industry systems – e.g. data management, customer billing etc
- Costs associated with half-hourly settlement (for some forms of automated DSR - or, possibly more frequent validation for Balancing services)[113].
- Customer-facing equipment – displays, other electronic products.

Equipment-related costs are likely to reduce with volume – but transaction-related costs may not. A key question therefore remains at what point volumes will start to drive down equipment costs – and how in practice these volumes are likely to be achieved.

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111 (expected cost ~£12bn to 2030 (but both electricity and gas). Estimated to account as a net increase in end-bills of less than 1% by 2020 - £40 annual saving & £15 annual cost). CHECK -https://www.gov.uk/policy-impacts-on-prices-and-bills#the-impact-of-decc-policies-on-household-energy-bills. March 2013

112 Nick Hunn of Onzo in his smart meter paper (November 2013) – www.creativeconnectivity.org - points out that development of truly interoperable, robust and enduring standards and protocols for wireless communications – which remain capable of maintaining connectivity & being updated over time - is a costly & resource intensive development project requiring strong leadership.

113 Depending on the nature of the demand-side service provided

Household Automated DSR : Possible Benefits

Potential benefits available to participating household customers are also not well defined or understood – either today or looking ahead to the 2020's[114]. This includes :

- What value may be on offer from different demand-side revenue streams – and when.
- How any savings to market actors would be shared with customers.
- How approaches to retail tariffs might develop (beyond RMR) ?
- The ***added*** value which automated control may bring over 'voluntary' customer participation – i.e. through 'firmness' of automated service and / or value attributable to other non-monetised benefits such as convenience and comfort.
- Which automated appliance types (e.g. heat ; wet appliances) might be capable of delivering the greatest demand-side cost-savings to which market actors.

4.4.3 Cost to household customers : how much will customers pay for the added electricity demand-side benefits of automated control ?

From a customer viewpoint, even once both smart meters and half-hourly settlement are available, any *additional* cost in terms of communications or control equipment which may be needed to facilitate automated DSR, would *need to have a reasonable payback* (to a customer and / or an aggregator) in terms of the value obtained by the customer in allowing their automated demand response.

On the energy side, smart thermostatic controls such as BG's Hive, the Tado, LightwaveRF and the Nest (in US) presently seem to retail for between £150 and £200[115]. In the US, retail of such smart thermostats is being integrated by energy companies either into rate plans offered to customers or into offers of 'rewards' for summer peak-avoidance.

At a recent conference, one EU example given of costs associated with a (non-energy) smart-activity in a 'connected home' were as follows : $50 (sic) for a home controller with one sensor to connect a single appliance (in the absence of market-ready smart appliances) ; extra sensors may cost £30-40 per sensor or device….implying 'a couple of hundred pounds' to connect different types of appliance. There may also be a monthly service charge[116].

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[114] **For the smart meter roll-out** : only a small part of the overall smart meter benefit is attributed to load-shifting – which in any case, is almost certainly estimated on the basis of 'voluntary' customer actions in response to a ToU tariff - rather than automated or remotely controlled DSR and load-management.

[115] In GB, an installation visit may be an added cost for 'wiring-in' the thermostatic control.

[116] Smart Home Opportunity. Michael Philpott. Consumer Practice Leader and Principal Analyst.. Ovum. 11 December 2013. Westminster eForum Seminar. Smart living – connected devices, utilities and infrastructure. These numbers are from a transcript and have not been checked back with the speaker.

Another estimate suggests that multiple zigbee-controlled sensors or devices could add £15 - £100 depending on the physical coverage of the mesh radio nodes and the location of the appliances being controlled[117].

However, for many GB households, today's costs of demand-side automation are likely to seem unduly high against the available benefits[118]. Interestingly, a small group of householders involved in recent qualitative research on smarter heating controls for DECC, were found to have 'unrealistic expectations about payback time, expecting to see savings after a year, especially older participants'. [119]

At scale, the costs of automated appliance control may expect to reduce. However, today's order of costs noted here for automated control for household level DSR, suggest that from a customer perspective benefits will need to be clear and quantified.

4.4.4 Conclusions on main commercial issues for future development of automated demand-side control for households

With some clear exceptions (eg smart thermostatic controls), automated household control for electricity demand-side purposes cannot yet said to be approaching commercialisation in GB.

As seen, the smart meter roll-out and arrangements for the consumer access devices are expected to support a market in smart goods and services - including for an automated household demand-side.

From our limited discussion here of some of the commercial issues associated with future development of automated control of the GB electricity demand-side for households, four issues stand out :

- **Product-related costs of household automated load control can expect to reduce quite rapidly with volume** : given the many automated applications which already exist in the commercial buildings sector, much of the technology is 'market-ready' and not novel or complex. Practical questions around installation and successful connectivity will however take time at the household level. As will development of consumer interest and consumer 'pull'. The major outstanding question for the product supply-chain remains the need to obtain a better understanding of the potential timescales associated with a likely need on the part of the electricity sector for automated household load-control at scale in order to improve the cost-efficient operation of the electricity system through household demand-side services. Such a forward view is important – not least so that a robust supply chain can start to ramp-up gradually over time.

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[117] Nick Hunn. Smart Meter paper.p.8 November 2013. www.creativeconnectivity.org

[118] SF Paper 8 – looked at the costs and benefits of DSR – and concluded that the full costs of DSR are rarely taken into account – whereas the benefits invariably are.

[119] 'What people want from their heating controls : a qualitative study. October 2013. Report for DECC by new experience. Data collected from 60 people across 43 households and follow-up with 19 people.

- **Considerable uncertainty attaches to both the costs and benefits of developing automated control for household DSR at scale**. A systematic assessment of the potential costs and the potential benefits of developing an automated GB household demand-side out to 2030 may help to address some of the uncertainty presently faced by those looking to develop a GB market in automated household demand-side services. . Our very limited understanding, of the current costs and future benefits of household-level automated control for demand response, as set out in our Paper 8 and in the paragraphs above, suggests that a more systematic analysis of the likely costs and benefits may help to clarify both where the gaps are for further development work beyond the smart meter roll-out - and therefore how possible future innovation funding into projects associated household DSR and automated control, might best be focused for the near to medium term.

- **The business case for automated household demand-side control also needs to be informed by a better understanding of likely developments in future wholesale costs and prices** – in particular the impact of wind. We took an initial look at this very complex area in Paper 9[120] – but others need to take that initial work further. Not least, if approaches to retail tariffs are eventually to shape development of the GB household demand-side, then the role of wind in driving wholesale costs and prices – and the potential knock-on implications for retail tariffs – will need to be better understood.

- **Putting the separate elements together at scale to develop an automated GB household demand-side is not just about the costs and benefits. There are commercial, institutional, social and logistical 'end-to-end' issues which trials to date have not tackled.** Development of the I&C market will hold some lessons for an automated household sector – but the 'end-to-end' commercial (e.g. attribution of benefits among players ; benefit 'share' with customers ; distributional impacts) and institutional issues (e.g. settlement, billing, aggregation etc) need to be better understood at the household level too – and this should be a focus for innovation funds.

- **There is a need to develop a better understanding of wider market uncertainties, including possible policy and regulatory gaps, relating to future development of automated household control and demand-side development.** The cost-benefit and commercial uncertainty faced by those wishing to invest or develop automated demand-side services for household customers at scale sits within a context of a wider market uncertainty in which the household demand-side sits. The GB electricity sector is characterised by a complex framework of wider policy and regulation – much of which is at present in the throes of being re-defined, or, in the early stages of implementation. This is true not only for smart meters and the accompanying arrangements for automated DSR services discussed in the first part of this chapter – but also importantly for the evolving context of the GB electricity markets (EMR, capacity market) and any future demand-side role in those markets – as well as regulatory developments in our retail

[120] Sustainability First. Paper 9. GB Electricity Demand – 2012 and 2025. Impacts of demand reduction and demand shifting on wholesale prices and carbon emissions. Results of updated Brattle modelling.

markets (RMR), and now too, a likely reference to the Competition and Markets Authority.

As noted, Ofgem in its Smarter Markets work has acknowledged the need for a DSR Framework[121], and this is a welcome step.

In discussion however, it was evident that the lack of a generally understood chronology or a 'forward-looking' framework to capture in a very high-level way how the electricity demand-side, and especially the household demand-side, may evolve going forward in the far wider context of the development of the GB electricity markets, may act as a deterrent upon those who may otherwise wish to take forward customer-facing innovation and customer offers in the household demand-side area.

Some pegs are now 'in-the-ground' (especially smart meters) but many other uncertainties remain and are yet to be clarified. Without improving the general understanding of how a GB electricity household demand-side may develop from now to 2030, it is hard to see how or why either market actor commercial 'pull' – and / or customer 'pull' - will develop, other than 'niche' applications. Even where some value may be available to market actors and so to their customers, that value may remain unexploited without a clearer long-term 'view' of how the market may evolve. This in turn could leave costs on the supply side not being addressed by demand-side solutions, even where these may be potentially cost-efficient.

Beyond Ofgem's initial market-framing exercise of a DSR framework, Ofgem and DECC may therefore also wish to consider the benefit to the market of a wider and longer-term 'forward-look' - including a basic 'gap-analysis' – to support those with a long-term commercial interest in developing the GB household demand-side. Such a forward view would help to clarify the likely time-scales associated with development of an automated household demand-side – and therefore help to pin-point and prioritise those areas (1) where further trialling and / or innovation funding could address unresolved problems and (2) where there are issues not yet being addressed either by policy or by regulation [122].

121 Ofgem. 'Creating the right environment for demand-side response : next steps'. 16 December 2013

A DSR Framework which will formalise the interactions and practices among different actors in the value chain who use DSR, to support industry parties in being confident that investment in demand-side response is justified.

122 DECC / Ofgem Smart Grid Forum Work Stream 6 is undertaking detailed work to understand what regulatory changes may be needed over the next decade or so for the GB demand-side to function well.

One way to start to develop a wider electricity demand-side 'forward look', including some broad economic analysis, may be through development of new electricity demand-side scenarios around which a market 'view' could start to coalesce. For example, these might start to build upon the recent UKERC Scenarios for the Development of Smart Grids in the UK. Synthesis Report. UKERC/RR/ES/2014/002. February 2014.

Chapter 5 : Household Level Thermal Storage

5.1 The potential for an increased role for household level storage in the GB electricity system

Introduction

Our second example of customer-serving innovation relates to the potential for an increased role for household level storage in the GB electricity system. Forms of storage could have an increasingly important role to play in the electricity system in the future– as part of a suite of techniques for better balancing of demand and supply. Storage can be used to provide back-up energy (e.g. in power cuts) or to ensure energy remains available when intermittent sources (such as wind or solar) are not available. Storage can also provide other services such as peak-load reductions, balancing / ancillary services, and transmission and distribution services. As noted in the Government's heat strategy consultation 'To limit the grid and generation-based challenges of supplying heat via electricity, and to limit bills, the use of storage in tandem with electrical heating will be important'.[123]

Storage of electricity is not as straightforward as storing other forms of energy (e.g. coal and gas) so it has not formed a major part of the electricity system to date. However, the need for and scope for storage could increase with the increased use of intermittent commercially 'must-run' power sources (wind and solar) and new demands for electricity from heating and vehicles. Networks are already facing issues with how to manage solar PV volume and need to work out how best to make use of demand-side and storage. The system may increasingly need demand to follow low-carbon generation.

There is a lot of interest in developing storage technologies to operate at small and large scale and this is likely to be a major area of innovation in the coming years. However, many storage technologies are currently very expensive and there are many practical, commercial and regulatory issues that may mean their widespread adoption could be many years away. In the household sector this is particularly true as currently available retrofitted storage options (for example as being trialled in some LCNF projects) are expensive, large and difficult to fit into the average house.

In Chapter 5 we focus solely on one possible area for the development of storage – thermal storage at household level. This is because we consider that this potential is under-recognised at present and that there may therefore be a risk of missing out on a cost effective short-medium term option for demand response.

[123] DECC. The Future of Heating: A strategic framework for low carbon heat in the UK. March 2012

We note that responses to the DECC heat strategy made a similar point :

> 'DECC should consider the benefits of storage heating in more detail because of the simplicity it offered as well as the network benefits. Storage heating was currently missing from a number of Government energy models where only instantaneous electric heating was considered'.[124]

We have identified in previous papers[125], that there could be considerable value in demand side response in the short to medium term (i.e. before 2020) to help reduce the need for new capacity – and this adds to the value of doing thermal storage.

The innovation issue (and hence why we are including this topic in this paper on customer-facing 'innovation') is only partly in terms of the technology required - we outline some technology developments and refinements. But perhaps more important is the need to find ways to innovate in terms of incentives and policy to access and realise the potential of thermal storage at the household-level.

5.2 Types of storage in the electricity system

Storage can be either (1) electricity or (2) heat (thermal).

- **Electricity storage techniques include** : primary (superconducting and capacitor technologies), mechanical (e.g. pumped hydro, flywheels), electrochemical (batteries – e.g. including electric vehicles). Electricity storage technologies allow for the stored electricity to be reinjected into the electricity system.

- **Thermal storage technologies include** : storage heaters and heat stored as hot water (e.g. in a household hot water tank). Thermal storage cannot be re-injected into the electricity system – but instead must be used as heat or hot water (e.g. within a single building)[126]. The big advantage of household level / small-scale thermal storage is that it is currently significantly lower in cost than other equivalent storage technologies. This cost advantage is likely to remain for some years as many electricity storage technologies are still in development[127].

Furthermore, even with improvements in costs and practicalities of electricity storage technologies (including batteries for household level storage) there could there still be a role for thermal storage for some time to come, until such time as it becomes cost effective to move to all-electric storage.

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[124] DECC. Strategic Framework for Low Carbon Heat in the UK: Summary of responses. July 2012

[125] In particular, Sustainability First. Paper 9. GB Electricity Demand – 2012 and 2025. Impacts of demand reduction and demand shifting on wholesale prices and carbon emissions. Results of updated Brattle modelling.

[126] Or, not for discussion here, for distribution to a number of buildings via a district heating system (and which signifies more of a logistical and cost challenge).

[127] For example, informally understood from one LCNF project trialling household-level self-balancing of solar PV and battery, that cost of the four battery packs needed per home amount to ~£600 (i.e. £150 per pack).

5.3 Household level thermal storage - current use

The main role for thermal storage is to shift demand for electricity for heating and hot water to times of day when electricity is cheaper to supply and to reduce demand at high cost times. This could be either to:

- Help even out demand on the network side (and thus avoid or defer the need for new network capacity) or

- Purchase power at times of high supply (e.g. when wind output is high) and avoid power purchase when supply is short (e.g. when wind output is lower). This in turn could help to avoid the need for some future investment in generation capacity, reducing costs to consumers – including the costs of policies such as FiTs/CFDs and the capacity mechanism.

Thus thermal storage could play an increasingly important role as wind output becomes a more significant factor in setting wholesale prices for longer periods of time.

Another more near-term role for thermal storage could be to enable households with solar PV to maximise their on-site use of power from their system – and thus reduce their purchase of grid supplied electricity.

It is worth noting also that there is another form of thermal storage at the household level – the building's ability to store heat, which is affected by how well insulated it is. This is another important factor in determining the practicality and customer acceptability of demand side response capability. **For example, a house that can retain 80% of its heat for an hour will be better placed to pre-heat at low cost times than one that loses 50% of its heat within an hour.**

Thermal storage is currently used for hot water and heating by significant numbers of GB households. There is the potential for short-term growth through better usage of the storage already existing and through some new use in both heating and hot water amongst:

- Households who already make use of electricity for heating
- Households who use electricity to heat hot water (for all or part of the year)

5.3.1 Hot water storage – current use

Households who use electricity to heat their hot water split into two main types:

- Those without gas or oil central heating who therefore use electricity to heat their hot water all year around (this will include most of the households whose primary heat source is electric on peak or off-peak – ~2.5 million households in GB).

- Those who use their gas or oil central heating in winter to heat hot water but who use an electric immersion heater in summer. The number of households who do this is not known.

The number of homes in England with hot water cylinders has decreased over time – from 16.7 million in 1996 to 12.5 million in 2009[128]. This is due to the increasing take up of combination boilers which do not need a hot water tank.

If in the future fewer homes have hot water cylinders then fewer could provide the storage option. Once someone has removed a cylinder they may be reluctant to re-install one due to the space it would take up. However, despite the decline in numbers, GB hot water cylinders could offer considerable potential for greater use of household thermal storage :

- **Households who rely mainly on electricity to heat water** : probably mostly already use Economy 7, but newer developments in hot water storage could offer them greater hot water availability and potential cost reductions.

- **Households who mainly use gas or oil to heat water** : the key issue will be the extent to which using electricity to heat the water would be cost effective compared to the alternative.

[128] English Housing Survey, 2009 http://www.communities.gov.uk/documents/statistics/pdf/1937212.pdf

5.3.2 Electric space heating – current use

Electricity is used as the primary source of space heating by around 10% of households in Great Britain. Most of this is electric storage heating.[129]

Table 5. Primary heating source in Great Britain[130]	
On-peak electric heating	**Off-peak (electric storage heating**
562,000 (2.4% of households in GB)	2 million (8% of households in GB)

- **In the case of the 560,000 households using on-peak electricity as their primary heating source :** then assuming suitable appliances are available (e.g. if the household can install storage heaters), coupled with good thermal insulation-levels and appropriate controls and tariffs, some (and possibly most) of this could be available for additional storage capacity.

- **Use of electric on-peak heating to supplement storage heating** : this is not likely to be a source of additional storage but this source of peak demand may be capable of some reduction if the efficiency of the storage heating and/or insulation of the property could be improved.

- **Use of electric on peak heating to supplement other sources of heating**: this is not likely to be a source of additional storage but this source of peak demand might be capable of some reduction if insulation levels are improved in those properties.

One manufacturer estimates are that there are 6 million storage heaters in the household sector in Great Britain (homes typically have 1-4 storage heaters), and the installed capacity is 18 GW, with a storage capacity of 125 GWh.[131]

On this basis, they estimate that the energy storage capacity of the present UK storage heater stock can be described (at 125 GWhrs) as over four times greater than the maximum storage capacity of the UK's present pumped storage capability. Namely :

- 10 times greater than the energy storage capacity of Dinorwig
- Nearly 100 times greater than the capacity of Ffestiniog

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[129] Household numbers in total (2010) GB – 26 million

[130] Source of data: English, Scottish and Welsh Housing Surveys for years as indicated in Table.

[131] Glen Dimplex E.ON presentation

The industry estimates that around 250,000 storage heaters and 350,000 electric panel heaters (direct acting so do not make use of off-peak) are being installed annually in Great Britain.[132]

Switching to storage heaters for the 560, 000 households who use on peak electricity and fitting electrical storage heaters instead of panel heaters could be a very valuable amount of demand response, that would enable the shifting of usage of electricity for heating from peak and high cost times to lower cost times of day (via thermal storage). We note that a longer term solution may also be heat pumps with storage. We return to this issue in the recommendations section at the end of this chapter.

5.4 New options for household level thermal storage

We identify three main options for increasing the role of household level thermal storage :

- **Enable households with solar PV to use more of the electricity generated on-site** - and reduce exports and imports, by diverting some of the electricity they might otherwise spill to the hot water tank. **This can be done on the customer-side of the meter and does not require the consumer to have any contract with any external organisation.** The consumer needs a solar controller/switch fitted to link the solar system and the immersion heater.

- **Enable hot water tanks (immersion heaters) , via automated systems, to respond to fluctuations in wholesale prices by being charged up at low cost times.** This could be used particularly to charge up water heaters at times of high wind output and to reduce or stop import of electricity (which may otherwise be used for hot-water heating) at times of low wind output. This is likely to be developed under a contract between the energy supplier and the customer and will enable the supplier to optimise wholesale purchasing. **To do this will require some form of control so that the supplier can control charge times for the immersion heater** (expectation for this to be done via the smart meter and / or the CAD (consumer access device) arrangements). Some households may need a larger hot water tank to make this viable.

- **Enable storage heaters to respond in the same way as for immersion heaters as outlined above**. Again likely to be developed under a contract between the energy supplier and the customer and will enable the supplier to optimise wholesale purchasing. **To do this will require some form of control so that the supplier can control charge times for the storage heater** (expectation for this to be done via the smart meter and the consumer access device arrangements). Households with existing storage heaters may need to replace them with newer ones; those without storage heaters would have to buy / obtain them.

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[132] Glen Dimplex E.ON presentation

5.4.1 Hot water storage – new approaches

There are both retrofit and new options for increasing the use of hot water storage.

- **Retrofit example :** This involves a fully automated system for (1) monitoring temperatures in hot water cylinders and (2) based on wind forecasts using electricity to heat the hot water in those cylinders (thus defaulting to electricity for heat when it is low-carbon). We understand that an Irish demonstration project along these lines has been developed, which has been testing whether it can get the costs down to a cost-effective level. We currently do not have any more information on this project.

- **New example** : New hot water cylinders can have more advanced controls – so they can anticipate when hot water is running low for example. For demand respose purposes, the cylinders need two way communications and control. See the NINES case study box for more details.

There are a number of practical considerations for using hot water storage.

- **Most GB households tend to use their gas boiler to heat their hot water** (or off-peak Economy 7). To be cost-effective for the household, any intervention needs to be cheaper per/kwh than the alternative – and potentially significantly cheaper to payback the capital costs of any upgrading required (solar controller, larger tank, automated controls and switches etc) . In the case of using an already fitted solar PV system (i.e. where the household has already paid the capital costs) the effective per/kwh cost is presently zero[133].

- **Cylinder sizing**. Having additional buffers or larger cylinders allows more energy to be stored but may require significant additional space - which may not be available - and it may also increase thermal losses (unless heavily insulated).

[133] Unless the price at which a PV owner could export their power *exceeds* the combined value to the customer of their tariffs for FIT Generation and Deemed Export.

Modelling integration of hot water storage into the Irish electricity system

Integrating wind power using intelligent electric water heating. Niall Fitzgerald, Aoife M. Foley, & Eamon McKeogh. Belfast & Cork Universities.

A recent paper described the results of modelling the potential for storage via electric water heating to assist with wind power integration in the Ireland electricity system [134]. The model showed how a **simulation** of intelligent control for an electric water heating unit resulted in potential reductions in the system marginal price of electricity of up to 38% and better integration of wind power. Peak shedding for Ireland of up to 160 MW was estimated as achievable based on 100,000 units. Electric water heating showed estimated benefits for storage during 24 h periods where there is a large variation between the maximum and minimum wind power generated. The model indicates that only when wind power penetration exceeds 30% can electric water heating in Ireland provide more than 175 MW of load.

The model also showed that electricity consumption in Ireland would not reduce (indeed in some cases it would increase due to larger hot water tank sizes) but moves to less congested times on the system. The paper found that such a programme would also enable a more efficient and flexible operational and management regime for the system operator. As far as customers are concerned, the paper's authors concluded that the impact on customer bills was not easy to assess. They noted that their modelling showed some customer benefits **in terms of greater availability of hot water throughout the day.** However, some customers would need to install larger hot water tanks to participate and this would raise cost and practicality issues.

The paper did not consider the costs associated with increasing tank sizes, installing intelligent (smart) thermostats and additional insulation, which it recommended would need to be investigated. The paper also recommended further modelling at a larger scale to investigate other system benefits such as effects on the ancillary services markets and customer interest.

[134] Niall Fitzgerald, Aoife M. Foley, Eamon McKeogh . Integrating wind power using intelligent electric water heating. Energy 48 (2012) pp.135-143b

5.4.2 New generation storage heaters

New generation storage heaters[135] seem to offer a number of advantages over older storage heaters and direct acting (on-peak) electric heaters, particularly for demand response and customer convenience, comfort and running costs.

These modern storage heaters are designed to operate on any off-peak tariff – not just the older Economy 7 or Economy 10 tariffs used with older storage heaters. Some other features of these newer heaters are:

- Electronic user interface with LCD display with : room temperature setting ; seven-day programmer ; diagnostics
- Fan-assisted output for rapid heat-up time – (and quieter fan)
- Boost feature – to ensure heat is always available even with unexpected demand
- Depth – similar to a double wet radiator
- Optional communications link : for remote adjustment ; for demand side management

A key feature of these 'new generation' storage heaters is that they can provide different kinds of demand response, storing energy during periods when non-despatchable low-priced renewable power is widely available (e.g. when grid connected solar, wind, hydro are producing) - and releasing it for heating later to avoid the need to consume at higher cost periods.

To do this 'point-to-point' (as of today) the heaters have a transceiver which connects via an in-home system manager / controller (Hub) that facilitates two-way communication between the appliances and the energy supplier. Such hubs can be wholly automated and pre-set – without a need for user input The hub in the Glen Dimplex Quantum system is A5 size and may be mounted anywhere within the property[136] .

Main potential for new generation storage heaters in the near term future (e.g. to 2020) will be for households without access to gas, particularly those using older storage heaters and forms of direct acting electric heaters. We return to the question of how to facilitate this in the recommendations section.

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[135] For example, the Glen Dimplex Quantum system

[136] As discussed in chapter 4, for the future in GB, the communications may expect to be routed via the smart meter communications hub and a consumer access device.

NINES Northern Isles New Energy Solutions [137]

The NINES project aims to develop and manage the electricity distribution network more effectively to allow renewable energy to play a bigger part in meeting Shetland's energy needs. NINES will also help SSE plan for the replacement of the Lerwick Power Station, which is nearing the end of its useful life, with a smaller station than would otherwise be required.NINES, is being developed by SSE with a range of partners, including Shetland Islands Council, Hjaltland Housing Association and Shetland Heat Energy and Power. **Key aspects of the project include replacing older storage and water heaters in 750 homes with modern 'smart' ones.**

The household technologies were tested in a Low Carbon Networks Fund Tier 1 Project. SHEPD partnered with Hjaltland Housing Association (HHA) to identify six tenant households. Participants were offered a £100 incentive payment.

SHEPD (Scottish Hydro Electric Power Distribution) partnered with Glen Dimplex to develop and trial a new range of energy efficient storage heaters and hot water cylinders (immersion heaters) designed for : grid energy storage, demand side management and frequency response. In addition to these network benefits, the design was projected to benefit customers by providing a more efficient and controllable heating system. Aims were to prove the integration of these technologies and to generate learning for the wider roll out.

The Tier 1 project installed new heating and hot water systems in six homes in Lerwick, with communications back to a central interface, providing SHEPD with a degree of control over local demand and frequency response. **The water tanks are providing frequency response by a constant trickle feed which can be turned up or down as required to manage frequency. This is valuable because frequency is an expensive service to buy given that it has to be instantaneous.**

SHEPD[138] developed a control solution capable of communicating to the new heating systems and providing the following functionality:

- Control of the heaters via a daily schedule, through a Local Interface Controller (LIC)
- Remotely over-ride the schedule in real-time
- Automatic frequency response by the Dimplex Controllers and heaters
- Remotely provide updated frequency response characteristics to the Controllers
- Retrieval of data from the Controllers via the LIC and into a remote recording System

Installation was carried out by local plumbing and electrical contractors. Testing demonstrated the successful integration of components.

The sample size of six homes is too small to generate statistically significant findings. However, tenants considered the heaters to be more controllable and they were less likely to run out of hot water. Evidence suggests that households did not use any more energy overall than before.

The analysis recommended that design aspects (e.g. control system) should be refined for the large scale roll out to maximise the DNO's demand side management capability while maintaining user comfort.

This trial has demonstrated the functionality of the system and provided an initial indication of the network and customer benefits.

NINES project next steps – 750 home trial of storage heaters and hot water cylinders

Next step on the NINES project is to trial dynamic scheduling and control, via a large-scale roll out to 750 homes of storage heaters and hot water tanks, expected to offer 43 MWh of thermal storage. Informally, we understand that a high-level of initial customer interest has been shown.

SHEPD will install communications equipment and establish an Active Network Management (ANM) system to provide dynamic control functionality. The project will therefore allow the technology to be tested, both at scale and by integrating it into an existing system, thus enabling SHEPD to determine the value to DNOs.

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[137] SSE Slides. LCNF Conference. October 2013

[138] With Smarter Grid Solutions

5.4.3 Solar PV to water heater

400,000-plus households in GB now have solar PV systems, largely incentivised through feed-in-tariffs. Although feed-in tariffs have been reduced for new installations, many households are still installing the systems, particularly as the costs of solar PV have reduced markedly in the last couple of years. The feed–in tariffs in GB pay households for all the electricity generated by their PV system – whether it is used on-site or exported. This feature of UK feed in tariff policy (which differs from some other countries where customers are paid only for what they export) has stimulated an innovation in the market in the form of the solar switch or controller. There are a number of companies now selling these products in the GB market. [139]

Solar switch/controller systems are designed to monitor PV export and redirect it to the immersion heater or other electric heating source to maximise on-site use of solar PV electricity and minimize the purchase of grid supplied electricity. Some versions can work with off-peak tariffs to maximise grid purchase overnight using the solar PV during the day. Some versions can also direct the PV electricity to a second heating source such as a storage heater, Infra-Red Panel or electric under floor heating, once the hot water thermostat is up to a given temperature, although this may have less potential given that heating use is seasonal only. Some have a web-based or smart phone monitor system for broader home energy management purposes .

Other potential future uses of this technology could include hot water fill of appliances such as washing machines and dishwashers, most of which use cold fill at present (this may require some changes to appliance standards).

The advantage of these systems is they are relatively low cost (around £250-350) and do not require any plumbing or changes to the immersion heater or cylinder. They just need to be installed by an electrician (about 1 hour's work), making the installed cost in the region of £350-450. If a household has already made the decision to install a solar PV system then the incremental cost is low which should enhance cost effectiveness – the incremental cost may be even lower if the controller is installed at the same time as the solar PV system.

These solar switch/controller systems do not require the customer to enter into any contract with any supplier or aggregator - **as all the activity takes place on the customer side of the meter.** At low levels of adoption this is not likely to be an issue but widespread PV 'self-balancing' may make PV 'profiles' harder for market actors to predict (system operator, suppliers or networks) which in turn could perhaps create new operational or commercial risks for them.

For networks the reduction in PV unmetered spill may be beneficial in areas where clusters of PV are causing network disturbance. For networks, a main benefit would be if PV thermal storage led to less use at evening peak (but that would only be so if the thermal storage displaced peak-use of electricity).

[139] There are also some other systems to divert solar PV electricity to the immersion heater but these are more expensive, require plumbing expertise and tend to be viable only in certain circumstances.

We have found a number of different views about the practicality and cost effectiveness of these solar controllers amongst market actors that we have interviewed. On the one hand there are now a number of companies selling these into the UK market or planning to do so, including a number of reputable and well established businesses. A number of people that we interviewed also considered that this looked like a sensible relatively low cost and simple solution that therefore may offer a number of advantages over higher cost and more complex options.

Some others were more sceptical, questioning either whether these solar controllers would in reality be as low cost and simple to install as is claimed, or how well they would work or how cost effective they would be, particularly for people who mainly use gas to heat hot water.

There has not to date to our knowledge been any independent testing and verification of these devices. In view of this, as we would suggest for all forms of new technology, we would recommend that such testing be carried out as soon as possible, given that this appears to be a promising technology. We return to this subject in the recommendations section.

5.5 Innovation requirements for thermal storage and demand-side services

5.5.1 Technical innovation requirements

Most of the technology is already available for thermal storage to provide demand-side services in some form. But further improvements could be made to reduce the average unit costs of controls, switches, new storage heaters and hot water tanks. There may also be the scope for innovation to make some technologies more suitable for a wider range of properties – e.g smaller homes.

Smart meters are not essential to providing a greater level of household thermal storage – this could be done via centralised direct load control technologies[140] . However, as noted in chapter 4, 'point-to-point' communications and control arrangements (as in current trials) may be used, but smart meters and CADS (consumer access devices) currently look set to become the most likely communications and control options.

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[140] E.g. such as the radio teleswitch which has been used for many years to control storage heaters on Economy 7, but is being decommissioned – see chapter 4.

5.5.2 Commercial innovation requirements

Whilst technological innovation may be relatively straightforward for household thermal storage, agreeing and setting up the arrangements between different **market actors (suppliers, networks, aggregators etc)** is likely to require much more work.

Household thermal storage has a clear potential in the electricity system, but a main question is who would wish to buy it and what relationships do they need to establish with customers ? Household thermal storage could serve:

- **Network requirements (peak avoidance)**
- **Wholesale purchasing requirements of suppliers (peak avoidance ; wind matching).**
- **Balancing services to the system operator (frequency / fast reserve[141]) –** this is currently the highest 'value' service which a household customer could provide.

One 'back-of-the-envelope' estimate is that UK hot-water tanks, in principle, could collectively provide some 6 GW of storage [142].

Suppliers have suggested to us that they do not see any particular barriers to relationships with customers to provide thermal storage services, but as discussed in chapter 4, there is presently no clear commercial or business driver for this to happen. This suggests that there may be a need for some forms of intervention to stimulate this market if it is considered to be worthwhile. We explore some of the possible policy options in section 5.6 below.

5.6 Integrating household thermal storage into the GB electricity system

As noted, the main value to the electricity system of more thermal storage is a potential low-cost buffer to absorb 'must-run' output of non-despatchable renewables at times when electricity supply exceeds demand .

The chief value of thermal storage to the customer is the choice to put electrically-charged heat into the store at lower priced times. In turn, this offers them the chance to heat their hot-water and / or electric heaters more affordably than otherwise.

However, the reality of how more thermal storage might integrate into the GB electricity (and energy) system - particularly at major scale and possible impact on winter peak electrical load- is quite hard to foresee. For example : (1) how the capacity of thermal store 'buffers' might vary seasonally ; (2) whether GB winter-peak electric load might increase - unless

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[141] Until relatively recently, 250 MW of household storage heater load was contracted to provide fast-reserve services to the GB system operator between midnight and 7 am

[142] SSE Slides. LCNF conference. November 2013. Each NINES project tank capable of offering up to 13kWh of storage.

storage heaters only charge outside peak times ; or (3) perhaps, may make no difference to electricity use at all (e.g if the output of the thermal storage displaces gas).

The box below notes some of the possible complexities which would need to be better understood. There may be benefit in a GB research study along the lines of the Irish hot water modelling study noted above. We also include a box below on the PJM system that provides an illustration of how schemes might develop.

Integrating more thermal storage into the GB electricity and energy systems : some factors for consideration.

- **Thermal hot water –** this may have a peak-load 'benefit' in homes where on-peak electricity is displaced. In electric off-peak homes there would be no impact on peak-load. In homes where thermal storage of hot-water would **substitute** for gas or oil-use there could be an **added carbon benefit –** by saving carbon over & above the EU ETS cap **– but there may be no peak electricity benefit** (because electricity use may remain unchanged at peak (and other times)). Hot water storage is year-round – and this characteristic is arguably a major 'plus' in the ability to absorb 'excess' non-despatchable renewables all year round. This would be likely in all-electric homes. In other homes however, with gas or oil, the choice to heat water stores electrically would depend on which fuel was cheaper. So it is hard to say whether the main customer benefit to absorb 'excess' low-priced electricity would be chiefly in summer, or, all year-round.

- **Storage heaters –** could displace peak-electricity in homes which are on-peak electrically heated now. However, if wholesale (and retail) pricing becomes largely wind-driven – then unless there was also a ToU or other 'restricted-hours' incentive (along the lines of the CLNR heat-pump trial) and/or some form of automated control of charging times, then households might have an incentive to charge the heaters at times of high wind output (i.e. because it cost less) and this might create new 'network hotspots' if such high wind output times coincided with peak demand (we discussed in Paper 10) [143]. Similarly, as for hot water, if the storage heaters substitute for oil or gas there would be an **added carbon benefit**. Last, and importantly, **storage heating is seasonal – and so the ability to absorb wind or PV output would not be available from GB storage heaters in the summer months.**

[143] Sustainability First Paper 10. 'The electricity demand-side and local energy : how does the electricity system treat 'local'?'

PJM[144] Case Study: VCharge/ENBALA – Frequency response 'virtual power plant' from thermal storage

Demand response is integrated into PJM's markets for energy, day ahead scheduling reserve, capacity, synchronized reserve and regulation and can compete with generation in these markets.

In PJM's Energy Market, end-use customers participate in demand response by reducing their electricity use either during an emergency event or when locational marginal prices (LMPs) are high on the PJM system. End-use customers participate in demand response in PJM through members 'called curtailment' service providers (CSPs), who act as agents for the customers.

VCharge/ENBALA is one of a number **of pilot demand response providers of frequency regulation services** in the US, supplying up to 600 kW of balancing services to PJM, by responding to the area control error signal with a **2-second response time**. They have aggregated 250 electric thermal storage heaters, in 50 houses in a pilot for north-eastern Pennsylvania, **via a thermal storage tariff**. Aggregation means that not all customers have to respond to every call. The heaters operate as a "Virtual Power Plant" that simultaneously buys energy during inexpensive hours and provides ancillary services to the grid operator. Existing electric thermal storage heaters have been retrofitted with new controls, and new electric thermal storage heaters have been installed for some customers. Also, as a licensed energy supplier, they are also able to arbitrage energy prices, providing the lowest-cost heating energy prices of approximately 40 such suppliers.[145]

Water cylinders in the PJM pilot are 105 gallon. (power : 4.5 kW; energy : 26kWh). They use day-ahead Locational Marginal Price to respond to the PJM frequency regulation signal.

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[144] PJM – Pennsylvania, Jersey and Maryland

[145] Demand Response in the USA. A Review of Demand Response Program Designs and Performance. Doug Hurley, Paul Peterson, and Melissa Whited. Synapse Energy Economics. March 2013.

Also : RAP slides. (Richard Cowart). SEDC workshop. Brussels. 6 November 2013.

5.7 GB household thermal storage – what are the likely timescales ?

- **Small-scale household PV : diverting 'excess' power production to thermal storage –** nothing to stop this happening now , because neither a price signal, nor two-way external communication are needed.

- **Wind matching** – arrangements to heat in-home thermal stores on a wind-matching basis requires two-way communication. Also decisions about *when* to heat the thermal store *will be price-driven*. Therefore, a customer will need (1) an external communications interface (2) a price-related signal to send to the controller and (3) an automated controller which switches the storage heater or hot water cylinder onto 'charge' *when the price is low* (i.e. *when it is windy*)[146] . It would be feasible to do this 'point-to-point' (as in the NINES trial) now. However, using the smart meter system and / or communications hub and consumer access device would allow the **actual** electricity usage recorded by the smart meter to be matched to the price periods of the wind-related (dynamic) tariff[147]. **This suggests that household thermal storage and wind-matching at scale would most likely follow the smart meter roll-out** . This may also be when it has most value, because as we noted in our Paper 9, wholesale prices may start to become significantly more wind-led in the early 2020's.

5.7.1 Role of price signals

In discussion for this paper, a number of people considered that there were no major technology barriers to certain forms of demand response (which could include thermal storage) but that equally there was no real driver for action – no present business case and no clear incentives (as discussed in Chapter 4).

As we have noted before in our previous papers, the current largely flat pricing does not provide an incentive to avoid electricity use at peak times and maximise use at off-peak (low cost) times.[148] However newer more flexible dynamic pricing could help to incentivise a range of demand side response initiatives. The right tariffs could help to deliver some scale into this, which will be needed to provide a firm demand response - i.e – a supplier or network would need a minimum number to sign up for it to be commercially worthwhile and this would need to take into account the likelihood of use of override facilities by some households. Price signals may be important at scale, perhaps at particular 'network hotspots' to avoid electric storage heaters or hot water cylinders charging at winter evening peak (and at scale, questions may arise for the networks about the principle of customers effectively being 'constrained off' when it is windy at peak and the prices are low).

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[146] And vice verse with battery storage

[147] It would also be feasible to do this point-to-point, but some form of verification would be needed to satisfy the market and for billing.

[148] Sustainability First. Paper 7. Evolution of commercial arrangements for more active customer and consumer involvement in the electricity demand-side. (The only exception of course being households with Economy 7).

5.8 Household thermal storage : some recommendations for policy and regulation

Germany and California provide interesting examples of how storage is being coupled with renewable incentives (see boxes below). We are not currently advocating either of these approaches as policy options as we consider that there a number of other options that may be more suitable for short term application as outlined towards the end of this section. The Californian and Germany examples will however be worth watching to see how they develop.

To enable customers to provide more thermal storage into the electricity system, over and above the smart meter system, there could be a need for new investments including :

- New storage heaters
- Switches/communications to link the storage heater and hot-water cylinder to the market actor so that electricity can be switched on and off.
- Switches/controllers to link PV to hot water tank
- New hot water tank and immersion in some cases
- Improved insulation in homes to facilitate heat storage.

The three main options for incentivising such investments to facilitate greater household level thermal storage are :

- **Regulate/mandate**
- **Offer incentives such as grants and loans**
- **Change the price signals to the customer** In time we may find that price signals are a sufficient motivation without the need for other interventions such as regulation or grants or loans. (see section 5.6.1 above)

In this section we make some suggestions as to regulatory and incentivisation policies.

5.8.1 Regulate/mandate ?

There would be limited value in mandating household thermal storage in isolation (e.g. by setting some target) and it may cause distortions as the broader storage, automated control and demand response markets develop (all of which are interlinked). We are also mindful of concerns about additional regulation and / or adding to household customer costs.

However, potentially, some limited mandation in the following areas may warrant further thought :

- **A hot water storage capability for new-build properties** (or, this might be framed as a new-build requirement for some form of storage – which in the short term might be more easily satisfied by thermal storage - but in the longer term may be satisfied via a range of storage technologies as the market develops).

- **In new properties where electric heating is being installed, to require storage heaters, or heat pumps with storage - rather than direct acting electric heating which could add to peak demand.**

- **To tie the FIT entitlement for household PV, to a requirement for a solar switch / controller** (where the property already has a hot water storage cylinder), assuming that the cost effectiveness of such devices has been independently verified.

Two areas of EU regulation have also been raised with us that may merit attention: these are the extent to which existing or proposed regulations may inhibit the development of storage in the future. For example, BEAMA has highlighted some potential barriers that may arise from the Eco Design Directive Lot 2 :

- It is unclear how thermal stores such as hot water cylinders will be scored within Eco-design

- Multi-element hot water cylinders (which may be required to optimise with wind availability) may affect the overall calculation of performance under Eco-design.

5.8.2 Incentives - grants and loans

The Green Deal and Energy Company Obligation have an important role to play in incentivising insulation to enable homes to become better at storing heat. There is a need to keep increasing the number of homes that are well insulated, particularly if we are to move towards greater use of electricity for heating – be that via heat pumps or storage heaters. Better insulated homes will be better able to maintain heat without large spikes in electricity demand at peak times. **One important related issue is therefore the need to address solid walled properties – can we get better through innovation at reducing the costs of this measure and disruption and aesthetic impact factors?**

If thermal storage (and indeed forms of automation) are to progress and deliver their potential, they should be included as eligible technologies for the Green deal and ECO. At present, new generation storage heaters are Green Deal eligible, but it would appear that other technologies – including the necessary controls and switches – either presently for PV self-balancing – or in the future for DSR purposes - are not.

One question for DNOs to consider is whether there may be a future role for LCNF to support innovation in household level storage ? Alternatively, beyond LCNF into business-as-usual, whether the upfront costs of low-cost thermal storage at the household level could in some way be supported as an alternative to network investment ?

Policies to promote storage in California and Germany

Germany

In 2013 Germany began a new programme to support battery storage for households and small business. The programme is run by the state-owned but independently run development bank KfW, which raises money from the capital markets, mainly through bonds guaranteed by the federal government, which enables it to raise and lend money for approved purposes at lower rates than commercial banks. KfW has assets of more than €500 billion, and lent €73 billion in 2012 – one-third for renewables and other energy investments. From 2009-12 it provided €24 billion in loans for energy efficiency investment in 2 million homes, leveraging a total investment of €58 billion.[149]

The solar PV system and battery costs between €20,000 and €28,000 (average size around 7kW for the solar array; around 4kWh for the battery). The battery – lead acid and lithium-ion – is between €8,000 and €12,000. Finance is a combination of loans and grants - grants average around €3,000 and the average loan is around €17,000 at a 1.5 per cent interest rate. The program is not open to systems of more than 30kW or solar PV installed before 31 December 2012.

By late 2013 ,1,900 homes and small businesses had applied for loans and grants under the program - about 10 per cent of the money allocated in the initial phase. The program is aimed at early adopters, as at these prices (even with a grant and low interest loan), the investment is not cost effective. KfW estimates that battery storage needs to be half the cost it is now and this program is aimed at market transformation which should help to drive down costs. Once costs do start to fall (KfW estimate that within two years the investment could be offering a positive return), the grant component is likely to be withdrawn, although the loan program will probably continue.

KfW's stated aim[150], is to ensure that the output of wind and solar can be 'more decoupled' from the grid. 'The success of the Energiewende will entirely depend on integrating electricity from renewable sources into our energy system on a reliable, permanent basis'.[151] The rationale is to better balance supply and demand as currently there are significant peaks and troughs which are making it difficult for other generators to stay in business. This is seen as critical as the level of renewable penetration rises to around 40 per cent – a level expected in Germany within the next 10 years.

Over the longer term, KfW hopes that the program will help define standards for use of storage systems. KfW also expects to see storage developments for wind power and other larger solar systems.

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[149] http://reneweconomy.com.au/2013/germany-finances-major-push-into-home-battery-storage-for-solar-58041

[150] According to Axel Nawrath, member of the KfW Bankengruppe executive board

[151] Ibid.

California's energy storage mandate

California's renewable portfolio standard (RPS), is 33 percent of delivered electricity, with discussions about a possible increase to 50%. The California Independent System Operator (CAISO) considers there may be the potential for disruptions to grid operations as soon as 2015. California has adopted a mandatory target for storage capacity to further the integration of renewables into the grid and avoid the need for further fossil fuelled generating capacity to maintain supply at times of low wind and solar output. The mandate also aims to provide peak demand reduction, contribute to reliability needs, and help defer transmission and distribution upgrade investments.[152]

California's regulatory framework already encourages storage via high demand charges for commercial customers (which can be lowered with storage), and one of the only state-level self generation incentives that covers distributed storage.[153] The CPUC has also allowed both SDG&E and PG&E to develop significant storage investments and add them to the regulated asset base : $26 million in 2013 for SDG&E and $30 million for PG&E in 2011.[154] Most storage projects in other states are funded by government grants (e.g., DOE Smart Grid Stimulus Grants, American Recovery and Reinvestment Act), as a commercial business (i.e., not part of the regulated business), or as part of an R&D/pilot.

The new rule issued by the California Public Utilities Commission (CPUC) (AB 2514), instructs California's investor-owned utilities (Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E)) to procure 1,325 MW of electricity and thermal storage by 2020 and 200 MW by the end of 2014. It sets energy storage procurement targets for each utility at each point of interconnection, but allows utilities to defer procurement targets from one period to the next. Storage connected at the transmission level has the highest procurement target (700 MW), followed by storage at the distribution level (425 MW), and then customer-sited storage (200 MW). There is flexibility to shift procurement targets by as much as 80 percent between transmission and distribution grid domains.

Though the new rule was adopted by the five CPUC commissioners unanimously, two expressed concerns about the cost to consumers, especially as large pumped storage (hydraulic) facilities do not qualify.[155] A wide range of technologies do qualify, including batteries and flywheels, but costs are generally high. Some analysts suggest that the United States could have as much as 14 GW from storage by 2022, but only if storage costs come down to about $700-$750 per kilowatt-hour - current costs can be up to three times that.[156]

The mandate specifies that the utilities cannot own more than 50 percent of the storage projects they propose, to allow for new entry into the market. Projects must be judged to be cost-effective by the CPUC before they can be funded.

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[152] http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M079/K171/79171502.PDF

http://www.mercurynews.com/business/ci_24331470/california-adopts-first-nation-energy-storage-plan

[153] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA23F&re=0&ee=0

[154]

http://www.pge.com/includes/docs/pdfs/myhome/edusafety/systemworks/electric/smartgridbenefits/AnnualReport2013.pdf

[155] http://gigaom.com/2013/10/17/5-reasons-you-should-care-about-californias-new-energy-storage-mandate/

[156] http://www.energybiz.com/article/13/10/california-s-new-energy-storage-mandate-under-microscope

Chapter 6 : Automated Control and Storage : Consumer Issues

6.1 What do we know about the attitudes of GB household customers to automated control for demand response ?

Notwithstanding some of the technology and commercial challenges identified in chapters 4 & 5, the ability to combine household automation and small-scale thermal storage *together at scale* could, a decade or so from now, start to bring about a wholesale transformation on the demand-side by enabling energy consumers to become 'pro-sumers' . Use of power and heat in homes and buildings can be cost-optimised in a convenient way for the customer, including potentially across fuels – and, in principle at least, participating customers may feel genuinely more in control and therefore, possibly, more 'empowered'.

The key of course remains how consumers may feel about adopting automated control generally – as well as use of thermal storage which is also automatically controlled.

There is widespread international experience, research and evidence on customer response to demand-side automation, in particular with respect to smart thermostatic controls for air conditioning and heat. Customer acceptance seems generally high (albeit the meta-studies offer little detail on actual attitudes of different trial customers)[157], including among the fuel poor [158]. Assuming customer satisfaction and value, this perhaps augurs well for potential GB customer interest in smart thermostatic controls (currently marketed for gas heating but not electricity DSR).

GB Customer Experience of Automation : by contrast, other than customer attitudes to Economy 7[159], relatively little is known about GB customer experience of demand-side automation – not least, because trial experience is either limited or not yet generally available.

Of the smart trials noted in chapter 4, the published report to Ofgem of the largest GB smart-appliance trial by customer number – the nPower smart fridge trial of ~1000 appliances – did not discuss customer attitudes[160].

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[157] Demand Response in the Domestic Sector – a literature review of major trials. Frontier Economics and Sustainability First. August 2012. Report for DECC.

Also, 'The potential of smart meter enabled programs to increase energy and systems efficiency : a mass pilot comparison. Vaasaett report for ESMIG (European Smart Metering Industry Group). 2012

[158] PowerCents DC Program. Final Report. September 2010. Report by eMeter Strategic Consulting for the PEPCO Smart Meter Pilot Program. Sample of 900 households, including sub-sample of customers on limited incomes.

[159] 'From devotees to the disengaged. A summary of research into energy consumers experiences of Time of Use Tariffs and Consumer Focus's recommendations'. Consumer Focus. August 2012.

[160] CERT Final Report to Ofgem. Open Energi & KEMA. May 2012.

Although a far smaller sample size (around 150 smart appliances trialled in total), the CLNR findings of customer experience of remotely controlled heat pumps (~17) and washing machines (~150) will be of considerable interest when available[161]. Similarly, the household experience once all 750 homes for the NINES project are operational with thermal storage of heat and hot water will offer further good insight for the future into customer attitudes to automated control of these appliances. Last, the WPD ECHO 18-month project with the EST using smart plugs to control a variety of household appliances explicitly sets out to explore attitudes, experience and responses of 200 households to load control for the purposes of peak-avoidance. Findings likely to be available in 2015[162].

GB Customer Survey Findings on Appliance Automation for DSR[163] - pending more by way of empirical GB customer experience of smart appliances, we are left with consumer attitude surveys and focus-group experience. Such research tends to suggest that most respondents are willing to allow *some* control of domestic appliances (e.g. delayed start of wet appliances).

The findings of an Ipsos MORI 2012 Access Panel on-line survey[164] for the 2013 UKERC study on Transforming the UK Energy System were as follows.

Respondents were asked how positive or negative they felt about their electricity network operator controlling some of their appliances (for the purposes of balancing their electricity demand). The findings were as follows : 6% - very positive ; 29% - fairly positive ; 23% - neither ; 22% - fairly negative ; 18% - very negative ; 3% - don't know.

When asked about the 'acceptability' of allowing the network operator to control named appliances, answers as per the Table below, suggests that this varied by appliance-type. Perhaps unsurprisingly, remote 'turn-off' of those electronic appliances already on standby (TVs etc) and remote control of wet appliances – produced greater 'acceptability' scores among respondents than the question on acceptability of direct control of fridges and freezers.

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[161] Trials being conducted January – March 2014. Durham University will write-up customer attitudes thereafter.

[162] Due to end February 2015. ECHO – Energy Control for Household Optimisation. WPD LCNF Tier 1 project – www.westernpowerinnovation.co.uk/Tier_1_Projects/ECHO.aspx

[163] For example :

Survey : Demski, C., Spence, A. and Pidgeon, N. (2013). Transforming the UK Energy System : Public Values, Attitudes and Acceptability – Summary findings of a survey conducted August 2012. (UKERC : London). Pp25-27 & 54-55.

Focus Groups : Butler, C., Parkhill, K.A. and Pidgeon, N. (2013). Deliberating energy transitions in the UK – Transforming the UK Energy System : Public Values, Attitudes and Acceptability (UKERC : London). Pp. 37-41 & p. 51.

Literature Review : Scenarios for the Development of Smart Grids in the UK : Literature Review. Working Paper. January 2014: REF UKERC/WP/ES/2014/001 p.44

Dimitrios Xenias, Colin Axon, Nazmiye Balta-Ozkan, Liana Cipcigan, Peter Connor, Rosemary Davidson, Alexa Spence, Gary Taylor & Lorraine Whitmarsh.

[164] Nationally representative quota sample of 2,441 respondents

On-Line Survey : Acceptability of Control by Network Operator of Specific Appliances				
Appliance	**Acceptable % (very, fairly)**	**Neutral %**	**Unacceptable % (very, fairly)**	**D/K**
Electronic Appliances on Stand-by (TV, Digi-boxes)	78%	12%	10%	1%
Electric Shower. (automatic switch-off after 10 minutes (w. over-ride)	47%	19%	32%	2%
Washing Machine (customer to specify the time at which cycle must be finished)	48%	20%	29%	-
Fridge / Freezer (subject to temperature control).	30%	20%	47%	3%
Table adapted by Sustainability First from : Demski, C., Spence, A. and Pidgeon, N. (2013). *Transforming the UK Energy System : Public Values, Attitudes and Acceptability – Summary findings of a survey conducted August 2012. (UKERC : London).* ***Pp 54-55.***				

Earlier focus groups for the same UKERC study, suggested that the preferred method of automated demand management was one that was perceived as ‘enabling’ and that would allow householders to maintain a level of control. Discussants seemed to incline towards automation ‘with limits’ (e.g. with over-ride) over ‘externally controlled’ demand. Automation which offered ‘control over everyday lives’ was potentially seen as helpful.

Customer 'Journey'

A recent CLNR Update to Ofgem[165], gives some basic headline findings from a British Gas telephone survey of some of the 650 customers participating in the CLNR residential voluntary ToU tariff trial. These record that 83% expressed an interest in the idea of a smart appliance that would schedule their operation according to their tariff. However, this seemingly high proportion also needs to be viewed against answers which were more highly favourable to questions relating to the voluntary ToU tariff[166].

Perhaps the main insight to draw from those extremely limited BG customer 'headlines' might be about a 'journey' which reflects the fact that :

- Customers with experience of 'voluntary' demand-side activity (i.e. the ToU tariff) seemed well-disposed.
- This satisfactory demand-side experience may make a fair proportion of such customers open to a next demand-side step – such as automation.

That incremental approaches to demand-side development **now** may be beneficial in winning-over customers to automation in the long-run if we are really looking at a commercial **need** for dynamic tariffs by the early 2020's to better manage the affordability of wind on our system.

This impression that there is likely to be a 'customer journey' in terms of acceptance of automated control was also found in some focus group research carried out in 2012 for O2 (Telefonica) with Mumsnet **[167]**, where one reflection noted that 'for most parents, the promise of moderate savings from installing a smart meter is helpful, but the real appeal lies in time-saving activities, like being able to come home to a pre-heated oven. The smart home vision brings the benefits of smart meters to life'.

It is possible that if smart thermostatic controls for gas heating are well-received by GB customers who install them, that this may also help to pave the way to wider acceptability of electricity demand-side automated control too.

DECC is understood to be undertaking work on customer attitudes to and experience so far of smart meters and the likely 'pathways' thereafter for a positive customer journey to obtaining potential smart meter benefits.

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[165] CLNR Update. December 2013

[166] The BG telephone survey findings of some of their ToU customers were that : 94% of those questioned said they had found it possible to shift their energy use ; 93% expressed an interest in remaining on the ToU tariff ; and 95% said they would rather choose a multi-rate tariff over a standard tariff if it were available post-trial.

[167] 02 (Telefonica) Survey & Mumsnet Fieldwork 2012**.** The Mumsnet focus group took place over two weeks, from the 9th – 23rd August 2012 and members of the research panel were invited to take part via a discussion thread which attracted more than 130 posts.

DECC qualitative research on heating controls (October 2013) & on **smart heating controls** (December 2013) – Customers in focus groups declared themselves reluctant to 'cede' control *of heat* – especially appliances or devices they felt better placed to manage manually themselves. However, they expressed themselves potentially prepared to cede control where there was 'added value' in terms of things they would not *readily* do themselves – e.g zonal control of heat – and in which case, if this 'worked well' on an automated basis (eg via 'intelligent' control) they were also then prepared to cede remote control[168].

One interesting question is therefore how far it is important for customers to feel that automation allows them to be 'in control' – rather than that they 'are being controlled'. To some extent, marketing approaches may have a role to play.

6.2 What do we know about consumer attitudes to storage ?

As noted, storage heaters and remotely switched immersion heaters have been around for years. Historically, storage heaters have not been too popular amongst some users, the main problem being a lack of heat in the evening particularly in poorly insulated homes. Consumer Focus undertook some research in 2012 about existing time of use tariffs (Economy 7 and 10).[169] This work reached a number of findings on views about storage heating amongst those who use it. Among households that use storage heating as their main heat source:

- 25 per cent were dissatisfied with their heating system, and 68 per cent were satisfied, compared to 91 per cent of gas central heating users

- 59 per cent of storage heating users considered their heating system to be right for their needs, compared to 89 per cent of gas central heating users

The research also found that consumers who use storage heating as their main heat source tend to have lower than average incomes and are more likely to work in low skilled occupations or be economically inactive than those with gas central heating. Households relying on storage heaters are also more likely to live in purpose built flats or maisonettes rented from a private or social landlord and are much more likely to be under 34 or over 65 years of age than those with gas central heating.

But newer forms of storage heaters are more efficient. A cost-comparison from a manufacturer suggests that the comparative annual total running cost in a small home (one or two-bedroom flat) with new-generation storage heaters on Economy 7 may be as much as £100 p.a. less against all other fuels including gas (in equivalent properties with equivalent insulation levels). For a larger property (e.g. 3-bed semi) the total annual running cost was comparable with gas. An ability to charge storage heaters at different times of day should also make them more user friendly. Key to making them work will be getting good levels of

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[168] Rubens, S., Knowles, J. (2013). What people want from their heating controls: a qualitative study. A report for DECC. October 2013 – Final Report. new experience.

[169] http://www.consumerfocus.org.uk/files/2012/09/From-devotees-to-the-disengaged.pdf

insulation. Newer forms of storage heaters and more flexibility of time of day for charging should help (along with better insulation). But there has not been much consumer research in this area – which suggests a need for more (eg from the NINES or Greenway projects) - and for this to integrate with customer research on automation.

As noted, thermal storage for GB household customers could develop soon for customers with on-site PV - but may be some way off at scale if it is to be linked with wind-matching, because this would need to linked to price-signals and to fully functioning automated control (so, more likely to be cost-efficient once smart meter automation arrangements are established).

6.3 What are the potential costs, benefits and risks for consumers of automation and storage?

The recent Ofgem consultation 'Consumer Empowerment and Protection in Smarter Markets'[170] – looks beyond the smart meter roll-out[171] and aims to build on the goals of the RMR (Retail Market Review) of creating a 'simpler, clearer, fairer' retail market.

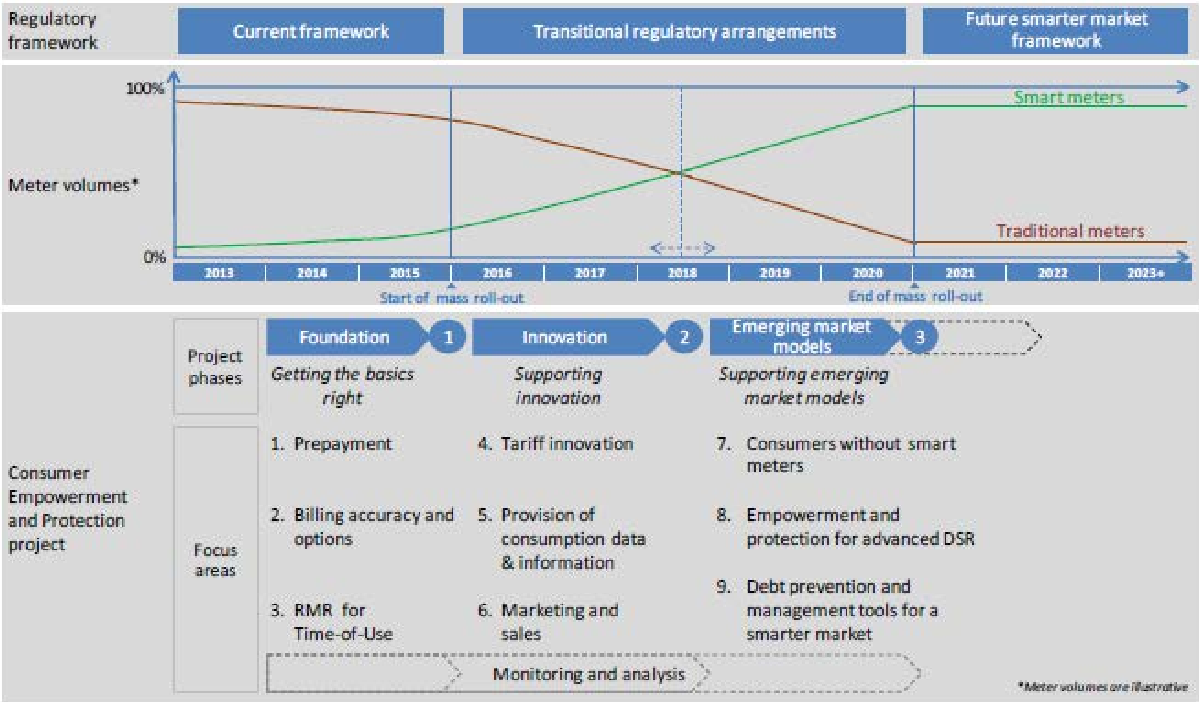
The Ofgem consultation proposals therefore rightly start to look well-ahead, beyond simple time-of-use tariffs to a world of more advanced DSR products and services – and how best to 'empower' consumers in that world.

Inter al, Ofgem has prioritised their work against (1) the 'immediacy' of consumer risks or opportunities, with a focus on 'facilitating the early realisation of key smart metering benefits for consumers' and (2) dependencies or interactions with external time-lines and market developments.

Ofgem has therefore split their work into three phases – without setting detailed objectives beyond Phase 1 – as illustrated in the following Ofgem figure.

[170] Ofgem. 16 December 2013. Consultation end-date 14 February 2014. (Figure 3)

[171] Protections relating to the roll-out are via the Smart Meter Installation Code of Practice



Ofgem notes that Phase 2 (which runs to when most consumers will have smart meters) will be when Ofgem expects 'significant innovations to emerge' which can help to deliver the consumer benefits of smart metering, but that work in these areas can only be 'meaningfully considered' after first allowing the market to develop further. Ofgem then sees itself better able to assess 'if the existing regulatory arrangements appropriately support market developments, if additional measures are required to better empower consumers to make use of the new opportunities, or if existing protections are proving inadequate in the context of emerging innovations.

On the basis of both the technical and commercial uncertainties we have identified in chapters 4 & 5 of this paper we are inclined to agree with the Ofgem judgement that significant consumer protection issues relating to **automated household demand-side control and smart appliances** are not likely to arise at scale until smart meters are extensively rolled out – plus the smart meter arrangements for automation (auxiliary load control switches, CADs) 'knock-through' more widely into developments in the market.

This may take us to the early 2020's, but from a customer viewpoint it also makes it important for Ofgem, DECC and others, including the consumer bodies, to get to grips **before this** with three areas identified in this paper :

- **Likely timescales attaching to development of the smart meter system automated control arrangements (including for existing Economy 7 customers ; auxiliary load control switches; consumer access devices) – and the likely GB time-line for other 'smart' appliances** – so that customers can enjoy a relatively trouble-free experience in terms of the installation and operation of any automated smart home appliances they buy, and be able to obtain any demand-side benefit as promised.

- **A more detailed understanding of the full costs and benefits for customers from automated control of appliances and the likely pay-backs by the early 2020's -** assuming a more wind-driven electricity system.

- **A need to set out a 'forward-look' of the market and policy steps needed to realise an automated GB household demand-side at scale and the main dependencies -** including for household level thermal storage. In turn, this would help to develop a better understanding of **when more complex dynamic retail tariff approaches may become of greater commercial interest to market actors – and so likely to become widely on offer to customers.**

In our earlier paper[172], we put forward a set of principles by which to judge customer offers in the demand-side market. In the light of our conclusions in this chapter on consumer issues, we regard these as still relevant (see box at end of chapter 6).

6.4 Customer data

Last, one **near term** and very important consumer area relates to **customer data**. This area is already well-recognised by Ofgem and DECC relates to **customer data** and the detailed safeguards created for customer privacy[173].

Even so, Consumer Futures pointed out to us that there may still be important issues to address, given that customer consent to data-access is potentially a basic 'gateway' - both to certain demand-side activities (including perhaps control and automation), and to wider customer-facing services[174] .

In chapter 3 of this paper, we touched on the significant commercial interest in and on the rapid strides likely to be made in exploiting household customer energy data. Moreover, we noted that due to technology advances, far more granular customer data is set to become available both **without a smart meter –** as well as with one.

We therefore conclude, in fostering a greater sense of consumer empowerment, in addition to the consumer protections being established, that Ofgem and DECC may wish to promote an early awareness among customers that their consumption data may have an increasing commercial or alternative value to others[175] – and that customers may therefore wish to understand what service or other benefit they may receive in return.

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[172] Sustainability First. Paper 8. 'Electricity Demand & Household Consumer Issues'

[173] Ofgem. Ibid. p.29. para 3.50 : consumer consent is required for suppliers to access and use consumption data which does not serve basic supplier functions such as billing. Active consent – i.e. **opt-in** – is required to access data that is more granular than daily and to use any data for marketing purposes.

[174] e.g. one example from Consumer Futures was a need for clear DCC verification arrangements that third-party intermediaries do indeed have customer consent regarding smart meter data access.

[175] See Jane Lucy start-up : Databara ltd – https://angel.co/databarta-ltd

Sustainability First. Paper 8 :Electricity Demand & Household Consumer Issues

Principles by which to judge the DSR market and particular offers

1 **Clear objectives and consumer outcomes** (e.g. lower prices, better integration of renewable electricity, protections for vulnerable consumers etc.)

2 **Distributional impacts** - have these been taken into account?

3 **Clarity** - how clear / simple is the DSR proposition?

4 **Appropriateness** to the consumer's circumstances

5 **Information** - adequacy, accessibility, comparability and privacy issues

6 **Flexibility** to switch between tariffs without significant penalties

7 **Choice** – on matters such as: automated response and controls and over-ride facilities; data sharing.

8 **Timing** – of offers - e.g. are they part of a wider energy efficiency scheme or on the back of new tighter product standards?

9 **Intermediaries and aggregators –** can customers access these and provide data to them if they wish; regulatory and consumer protections.

10. **Dispute resolution and remediation** - clear responsibilities and processes.

Paper 11

How could electricity demand-side innovation serve the electricity customer in the longer term ?

Part III – General conclusions and possible next steps

Part III – General conclusions and possible next steps

Chapter 7 : General conclusions and possible next steps

In this final section we pull together some general conclusions and set out some possible next steps. In so doing, we are chiefly seeking to offer some high-level reflections which those with an interest in electricity demand-side innovation funding and policy may wish to take forward.

This paper set out to answer the question of how innovation in the area of the electricity demand-side could serve the customer in the long-term. We tackled this question in two different ways :

- In the broad context of innovation funding, we considered how the LCN fund – as one major source of GB innovation funding – presently supports customer-facing innovation, given its main regulatory focus upon stimulation of network innovation – and

- By looking at two specific examples of customer-facing innovation (automated demand-side control, household-level thermal storage) – each with the potential to be transformational from a customer point of view. Both developments are supported by innovation funds to some extent. But each also faces additional technical, commercial, practical and institutional challenges before either a business case and / or 'customer pull' will emerge, and where policy or regulatory change may also be needed.

Specific conclusions are noted within each chapter of the paper,[176] but beyond these, we also note some more general conclusions below.

7.1 Development of the customer-facing electricity demand-side

The area of the electricity demand-side is high-profile for its potential contribution to delivery of a more affordable low-carbon world. There is an unprecedented level of interest and activity in GB and elsewhere in innovating for customer-facing developments in the demand-side area – be this on the part of the innovation community, the energy sector or the universities – and this is highly welcome. On the funding side, the relative scale of innovation funding in GB stands materially in-line with international comparators. Given that there are barriers to this innovation happening absent funding, this approach is welcome.

[176] LCNF – chapter 2 ; Customer-facing innovation funding – chapter 3 ; Automated demand-side control – chapter 4; Household thermal storage – chapter 5 ; Consumer issues – chapter 6.

7.2 Who is taking the 'forward view' on the GB electricity demand-side?

One area which repeatedly cropped up in discussion for this paper was the need for the market to obtain a clearer understanding of how an automated GB electricity demand-side may in practice evolve. This was particularly around the likely dependencies and chronology both on the I&C side and for households.

This matters both from an innovation and a customer viewpoint because two different worlds are fusing : the fast moving world of electronic communications and consumer products with a world where policy interventions and regulation still very significantly shape how this market will evolve.

Some pegs are already in the ground (smart meters, settlement for larger customers etc). But other necessary steps or pre-conditions remain somewhat ill-defined and / or some way off (e.g. half-hourly settlement, how the smart meter system, auxiliary load control switches, consumer access devices) might be used **in practice** to facilitate automated control. It is therefore hard for investors and actors (both small and large) who wish to innovate in this market to judge how it may evolve and to have an informed view about when development of the GB household demand-side may move from 'niche' to 'market' and so achieve scale. This uncertainty in turn makes it harder to make development of innovative household demand-side products 'bankable', to take well-informed commercial risks and to understand how costs associated with automated demand-side control will in practice reduce in time.

This is an area on which the ETI is focused, particularly as part of its Smart Systems and Heat Programme. Similarly, TSB's new Energy Systems Catapult is also likely to be active in developing a forward-view for the supply chain.

In its recent consultation response 'Creating the right environment for demand-side response: next steps'[177], Ofgem also recognised 'an urgent need' to develop a DSR framework to formalise the interactions and practices among different actors in the value chain who use DSR. Ofgem's initial aim is for industry parties to be confident that there is value for market actors in DSR to justify the investment. This is a helpful step, but beyond this initial exercise, Ofgem, DECC, TSB and others may also wish to consider how this initial market-framing may extend into a wider exercise to develop a wider electricity demand-side policy framework to support those with an interest in developing this market. This would also help produce a gap analysis to address some of the wider supply-chain uncertainties, including any main priorities for further demand-side innovation funding.

Extending Ofgem's initial market-model exercise into a broader demand-side policy framework in this way may help to resolve some of the tensions raised with us in discussion for developers / innovators more accustomed to a fast-moving environment - who find themselves dependent upon a more regulated environment to kick-start investment (smart meters, IHDs, Consumer Access Devices).

[177]Ofgem. 'Creating the right environment for demand-side response : next steps'. 16 December 2013.

7.3 Coordinating innovation funding initiatives on the customer-facing electricity demand-side

One area for further consideration, recognised by the NAO and others, is the area of coordination of innovation funds.

LCICG is intended to guide technology prioritisation and innovation programme planning over the next decade by the 17 government funders of low carbon innovation in the UK, building on their TINA (Technology Innovation Needs Assessment). LCICG published its Strategic Framework in February 2014, and covers 11 technology areas, including electricity networks and storage. The need for an overview for the electricity demand-side in terms of innovation funding gaps and priorities remains an important consideration for LCICG and the funding bodies. In particular, how **customer-facing problem areas for the electricity demand-side –** especially for households - could be funded and which area may best suit which innovation funding pot (or combination of funding pots).

The LCICG Strategic Framework has the potential to be very valuable. To maximise its potential there are five areas that we hope LCICG will address :

- It will need sufficient depth and sophistication in its analysis of how the electricity demand-side and future customer requirements will evolve to be able to assess whether innovation funding in this area is being properly focussed. Given the set of circumstances facing both the upstream and down-stream parts of the electricity sector, this means looking sufficiently far ahead (ie at least to the 2030s) and to take into account performance of different innovation options under a range of plausible scenarios for the sector and economy.

- Whether it is feasible to effectively fund cross-cutting work in the current funding landscape and to consider how joined-up working across funds can be facilitated, for example on DSR.

- How in practice to consider the LCN Fund (and NICs) within its strategic view. Although strictly-speaking not government-led, these parallel customer-funded awards, represent significant sums within the same electricity demand-side innovation space.

- To improve mutual understanding between smaller innovators and established industry actors and to bridge any ‘culture clash’ (TSB’s Energy Systems Catapult is expected to help).

- How to avoid unduly GB-centric solutions which may create unintended risks or disadvantage for product developers focused on international markets as well as GB.

7.4 Understanding the business case for electricity demand-side development

For the GB I&C electricity demand-side, many necessary pre-conditions are now in place for growing commercialisation of this market.

By contrast, for the household sector, it was evident in discussion that there is a current absence of a clear supplier business case and / or significant customer ‘pull’, meaning that customer-facing innovative demand-side solutions are not expected to be developed at scale in the near term.

Further, there are a number of wider uncertainties in the GB electricity markets that could act as barriers to business case development and where the likely impacts for the electricity demand-side, including the longer term costs and benefits, are presently very poorly understood. Notable uncertainties faced by demand-side developers include : the likely impact of EMR and the capacity mechanism on wholesale prices (so, the knock-on uncertainty around future demand-side business cases) ; RMR on the retail side (so uncertainty around future customer offers, tariff development and smart product development); as well as uncertainty associated with how the smart meter system and consumer access devices will facilitate automated control in practice (with a knock-on for customer-facing demand-side innovation).

While it is important to recognise that innovation projects inevitably operate and ‘commercialise’ in a world of uncertainty, it is also helpful to understand how far the impact of policy or regulatory uncertainty may be such that it acts as a brake or barrier on development.

We would therefore suggest that further development of electricity demand-side scenarios to improve understanding of likely time-frames for development of a household electricity demand-side may help to offer a better insight for investors and developers than exists at present[178]. This may also help to improve decision-making in the area of the customer-focused electricity demand-side in two basic ways:

- Innovation funders need this better understanding to properly prioritise market failures and funding ‘gaps’.
- Policy-makers would be better supported in attempting to assess how far innovation funding can ultimately be an effective alternative to regulation in driving a household demand-side market[179].

[178] These could build for example on the recent UKERC Smart Grid Scenarios. ‘Scenarios for the Development of Smart Grids in the UK. Synthesis Report. UKERC. February 2014. UKERC/RR/ES/2014/002. www.ukerc.ac.uk

Authors : Nazmiye Balta-Ozkan, Tom Watson, Peter Connor, Colin Axon, Lorraine Whitmarsh, Rosemary Davidson, Alexa Spence, Phil Baker & Dimitrios Xenias.

[179] For example, to assess how far system cost efficiency, reliability and affordability may be more effectively delivered by regulated approaches in a far more wind-driven and more low-carbon world (for example, as was done to create a market in condensing boilers and in energy efficient lighting).

7.5 Customer-facing electricity demand-side areas which may benefit from further policy attention and / or innovation funding

The two practical examples we considered in chapters 4 & 5 (automated control, household thermal storage) illustrated how innovation funding may in itself not be a sufficient solution to deal with some of the electricity demand-side barriers that still need addressing.

It is for DECC to consider where some of the outstanding policy obstacles may remain in development of a customer serving electricity demand-side. However, in developing this paper, we noted a number of areas where greater policy or regulatory clarity may be needed to unlock further electricity demand-side innovation at scale. Two of these were :

- The technical and commercial arrangements around the smart meter system and consumer access devices - to enable 'trouble-free' end-to-end connectivity and interoperability for those customers that desire it. For I&C customers, there is no generally developed view as to how standards for electricity demand-side participation may develop going forwards[180] . However, for the household sector, an in principle decision has been made that there will be common communications standards via the smart meter arrangements (so, in effect, 'regulated'). However, progress needs to be made in developing these arrangements so that a supply chain can develop and so that customers have a positive experience, and, that early investments in 'smart' equipment are not needlessly at risk of future obsolescence.

- Greater clarity on how the smart meter roll-out may impact upon likely development of a market in smart goods and services : not least, this in turn impacts on the questions discussed in 7.3 above, as to how far present innovation funding on the electricity demand-side is being awarded with a clear view about how this market is likely to evolve. The issue here is how far projects being funded today take a realistic view of the dependencies and time-lines associated with commercialisation, and how to focus on funding outcomes in projects which have a good chance of future commercial relevance.

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[180] Or as noted, how these may eventually integrate with commercial building management systems

7.6 Areas which may benefit from electricity demand-side innovation funding intervention ?

We have been clear that we believe it is for the LCICG and the funding bodies to coordinate and to consider how innovation funding should be prioritised and focused going forwards in the customer-facing electricity demand-side area.

However, in the discussions for this paper - and based on our two specific electricity demand-side examples of automation and thermal storage – we simply note some areas below which 'stood-out' to us as being where innovation funds and / or further policy interventions may provide a useful role in the service of customers in unlocking either new technical or new commercial approaches to electricity demand-side innovation.

7.6.1 I&C Customers

As noted, the I&C electricity demand-side is developing and is approaching commercialisation, and was not our main focus. However, two key areas where new technical and commercial approaches, perhaps initially supported by innovation funds, could help to deliver a step-change in how customers who are tenants or owners of commercial buildings could access potential electricity demand-side benefits. These are :

- The successful **technical integration** of the communications which may be used for control of demand-side services in the electricity market (balancing, capacity, peak avoidance etc) **together with** commercially available 'off-the-shelf ' building energy management systems already in common use to control HVAC and lights. (This may potentially entail development of more common approaches to communications standards).

- The development of **integrated delivery and business approaches** at the commercial building level which aim to successfully combine / exploit new GB demand-side revenue streams as these develop - **together with** the separate funding pots on the energy efficiency side. The aim would be to unlock new funding synergies, presently separated by institutional silos, to the benefit of commercial customers.

7.6.2 Household customers

Recent entry into the market by some new players with innovative products such as 'intelligent' thermostatic controls (in GB targeted chiefly at gas boilers) is encouraging in the sense that it suggests that customer-facing innovation can take-off if conditions are right.

However, the current lack of a supplier business case and customer 'pull' for the household electricity demand-side could mean that its development may stagnate in the absence of further funding and / or appropriate policy interventions.

We identified the following areas as worthwhile in this regard for possible further consideration :

- Practical demonstration of how to bring the GB household electricity demand-side together **end-to-end** across the value chain (so, not just technically). This is likely to involve customer-facing and retail-related R&D which can bring together innovation which *combines* a technology, behavioural & commercial focus.

- Exploring **integrated delivery approaches** capable of **combining** energy efficiency programmes and measures **with household electricity demand-side response programmes** (i.e. breaking open institutionalised silos, just as for commercial customers above).

- To join-up the policy 'no-man's land' which sits between energy efficiency, the demand-side and distributed generation. Tackle storage or community-level demand-side practical challenges (storage competition and community energy funds notwithstanding) to understand how to bring 'D3' together in practice.

- Optimising the demand-side across fuels – both at the household and community level – and in particular with respect to small-scale thermal storage. This area would benefit from desk-based economic and system modelling to understand the role of relative prices - as well as developing practical **customer-facing experience** through trials and pilots.

- Social innovation and customer-facing demand-side projects which put the customer / prosumer and / or community groups (including vulnerable customers) firmly 'at the helm' to demonstrate how customers can exploit their electricity demand-side value in the market. This could include, should they wish, the value of their data.

7.7 Is electricity demand-side innovation in customers' interest?

7.7.1 Data

We have seen how the volume and granularity of customer-data in GB which, with customer consent, may be 'exploitable' commercially relatively soon - not just by suppliers but also by third parties - may also start to shape a somewhat fast-changing commercial environment on the demand-side.

Ofgem's recent consultation on 'Consumer Empowerment and Protection in Smarter Markets'[181] sets out its current thinking on consumer protection in relation to provision of consumption data and information and marketing and sales. Ofgem, DECC and the consumer bodies are all mindful that the challenge for them will be to achieve a good balance between regulation and empowering innovation.

If the customer agrees, energy consumption data may well be merged with bank data, retail loyalty cards, health data etc. Therefore, hopefully customers will rapidly come to recognise that their meter data may have a commercial value (or other value) to others – and so understand the benefit or service they may receive in return.

Last, public policy for energy efficiency, for the demand-side, and for vulnerable customers stands to become far better informed by the future insight offered by better energy consumption data – **but this seems unlikely to happen without access to innovation funds.**

7.7.2 Safeguarding consumers

In chapter 6 of this paper we discuss consumer issues. Here in our conclusions, we would simply reiterate that in the long-term we would expect electricity demand-side innovation to serve customers in the following important ways.

- **Costs & benefits –** in engaging with the electricity demand-side the customer needs knowledge of the full costs, the full benefits and likely pay-back for them.
    - **Costs :** the full costs of upgrading to smart appliances, retrofitting control devices, thermal storage and insulation need to be clear and transparent to the customer. Other elements in the overall cost-benefit equation, include time taken to research and make the change, plus possible cost of 'inconvenience' (or even 'penalty') for participating in an automated demand-side scheme.
    - **Benefits (Customer Outcomes) :** the majority of customers would expect a lower bill than otherwise to be the main outcome and benefit of participating in an automated (or other) electricity demand-side arrangement. Other beneficial outcomes include improvements in comfort and control - plus enjoyment of an overall better standard of service delivery (ease & convenience).

[181] 16 December 2013 – consultation ends 14 February 2014. Pp 29-31

- **Empowering customers -** In principle at least, customer engagement with electricity demand-side automation should offer the potential to 'empower' customers in many different ways, by allowing **customers much individual choice in how they participate and how they 'access ' any available benefit.** In return for some form of reward some customers will allow third parties to take control of their electricity supply (or certain appliances). Some customers may choose to retain full control and cost-optimise themselves – which, with increasingly intelligent controls and two-way communications in and out of the home – may turn out to be the long-term trend. Some customers may also feel empowered by making their data available to allow others to create 'bespoke' services for them.

- **Fairness -** the question as to whether customers are treated fairly - in particular, helping to ensure that outcomes are delivered to a range of customer groups - including the most vulnerable remains central.[182] In terms of future fairness in a world with an extensive automated electricity demand-side, there may be a long-run risk that customers who either reject automated approaches, or who for whatever reason cannot access automated approaches, storage and insulation (e.g. because of upfront costs etc) could in the end become 'left behind'. This is **especially if automated control becomes essential in order to obtain any cost benefit in an increasingly wind-driven world.**

- **Vulnerable customers –** This question is clearly particularly significant for the most vulnerable, elderly or other disadvantaged customers. If affordable and appropriate demand-side automated control and / or storage packages are on offer to them, and subject to safeguards to assure their personal wellbeing, then they should stand to benefit equally from both the 'convenience' which automation may bring, together with any demand-side benefits or rewards. Handing automated control to a trusted third-party, especially with regard to 'intelligent' and 'smart' functionality, may enable groups of more vulnerable customers to access demand-side benefits which may otherwise be complex or difficult for them to directly access themselves. Suitable customer safeguards would be very important in terms of the nature of any demand-side agreement and the benefits on offer to such customers. **Services for vulnerable customers seems an area where innovation funding would be very worthwhile, as the 'market' may not naturally gravitate to developing automated demand-side and integrated home-storage and heating solutions, for these groups.** We found little evidence when evaluating the case for innovation funding that this is commonly considered (although the Expert Panel's assessment of the Vulnerable Customers and Energy Efficiency project by UKPN in the 2013 LCN fund competition is perhaps encouraging). If all customers are to benefit from future demand-side opportunities then this will need to change. Not least because **at least some innovation funding may be best targeted to finding solutions for the customer groups where there will be less of a market-driven push to innovation, including the vulnerable and the fuel poor.**

Frontier Economics & Sustainability First, April 2014

[182]In our earlier paper on household consumer issues we identified a number of key consumer areas relating to fairness for customers in a smart world. Sustainability First. Paper 8. Electricity demand and household consumers.

Paper 11

How could electricity demand-side innovation serve the electricity customer in the longer term ?

Annexes

Annex 1 : Electricity Demand-Side : Innovation Funding Sources

1.1 GB Funding Sources

This Annex describes key funding sources in GB. Coordination across these sources is provided by the Low Carbon Innovation Co-ordination Group, which coordinates low carbon technology funding from different public sector sources in the UK to try and maximise the impact of funding.[183]

1.1.1 Ofgem

Low Carbon Networks Fund (LCNF)

Ofgem's LCNF provides funding to electricity distribution network operators (DNOs) for innovative technical, operational and commercial projects. It has up to £500m of funding available between 2010 and 2015. Projects must be at the trial stage having passed R&D. They must not be ready to be business as usual to receive funding. Projects must make a contribution to decarbonisation and generate new knowledge that can be shared between all network companies. They must provide net financial benefits for DNO customers (rather than saving costs elsewhere in the energy sector). DNOs are encouraged to partner with organisations across the sector, e.g. suppliers and technology manufacturers.

Network innovation competition (NIC)

Ofgem's Network Innovation Competition (NIC) started in 2013. It is similar to the LCNF, but with a broader eligibility as there is one competition each for gas and electricity annually. All RIIO network companies are eligible. The scope for innovative projects is also broader than for the LCNF. To receive funding, companies must show that the innovative project will deliver value for money and low carbon and environmental benefits for consumers. The available funding was set at £27m per annum for electricity transmission. When distribution was added to the electricity NIC, Ofgem stated that a funding cap of £60-90m per annum should be made available for the electricity NIC from 2015, which includes the £27m figure for transmission. The total funding will be reviewed following the outcomes of the LCNF review which Ofgem plan to conduct in late spring 2016.

Network Innovation Allowance (NIA)

The NIA replaces the Innovation Funding Incentive (IFI). It is an allowance provided by Ofgem to electricity and gas distribution and transmission companies for small scale innovative projects delivering benefits to network customers. Companies must justify their NIA level in their business plans, with funding of 0.5%-1.0% of allowed revenues provided based on the quality and content of their innovation strategy.

Innovation roll-out mechanism (IRM)

Under RIIO, the IRM provides funding for transmission and distribution companies to roll out innovations with cost effective carbon and environmental benefits.[184] The

[183] See: http://www.lowcarboninnovation.co.uk/.

funding is for proven innovative solutions that would not be viable within the price control without funding.
Companies must apply to Ofgem for the funding, which is applied as a revenue adjustment within the price control period. Ofgem proposed that companies can apply for IRM funding in two windows during the price control. Funding must be above a materiality threshold.

1.1.2 DECC

Heat storage competition

DECC ran a competition in partnership with the TSB on heat storage technologies, which aimed to assess the viability of compact heat storage in addressing network constraints under conditions imposed by decarbonisation. Bidders that submitted successful feasibility studies to DECC are taking part in a one year prototype demonstration running from spring 2013 to 2014. This may be followed by a further demonstration phase.[185]

Energy Entrepreneurs Fund scheme

DECC runs a competition to fund the development and demonstration of innovative technologies or processes in energy efficiency, building technologies, power generation and storage.[186] Funding is available to bids from across the private and public sector, with a focus on supporting small and medium enterprises. The scheme is currently in its second phase, with £16m of funding allocated to date. The remaining £19m is being allocated through six monthly competitions where up to £1m is available per project. Projects must be completed by 31st March 2015.

Energy storage innovation competition

DECC awarded funding for feasibility studies of innovative energy storage under the Energy Storage Technology Demonstration Competition (part of the Small Business Research Initiative). The competition aimed to support innovation in pre-commercial

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[184] Ofgem, 2012, RIIO-T1 and GD1: Draft licence conditions – second informal licence drafting consultation, available at: https://www.ofgem.gov.uk/ofgem-publications/53622/riiot1andgd12ndlicencedraftconsultation.pdf; and Ofgem, 2012, Strategy consultation for the RIIO-ED1 electricity distribution price control Outputs, incentives and innovation, Supplementary annex to RIIO-ED1 overview paper, available at: https://www.ofgem.gov.uk/ofgem-publications/47144/riioed1sconoutputsincentives.pdf.

[185] See: https://www.gov.uk/government/publications/advanced-heat-storage-competition.

[186] See: https://www.gov.uk/government/publications/energy-entrepreneurs-fund-second-phase-documents.

energy storage technologies.[187] A second round of the competition awarded funding of up to £17m for a demonstration phase, with projects required to be completed by 31st March 2015.

1.1.3 The Technology Strategy Board (TSB)

Small business research initiative (SBRI)

The TSB runs the SBRI, which provides a platform and structure for government departments and other public bodies to run competitions which pose operational or strategic policy problems and invite businesses to pitch ideas for how the problem can be solved.

The SBRI runs a two-phase process. In the first phase, the successful receives funding to develop the proposal into a proof of concept. There is then a second phase where more money could be given to the firm to develop and prototype the idea. The innovation is expected to be commercialised by the firm (who retain all the IP), and the sponsor department might itself be the ultimate consumer of the product.

Some of the competitions under the SBRI relate to energy. The SBRI has recently been expanded in scope – around £200m of money is supposed to flow through it in 2014-15.

Innovation competitions

The TSB runs a wide range of innovation competitions in a variety of areas. These vary in size and scope. Currently a small number relate to energy, including competitions on:

- innovative measures that will improve the energy performance of traditional and historic buildings;
- whole system design for energy efficient high performance computing; and
- localised energy systems - a cross-sector approach.

Some of these competitions are part of the SBRI.

Catapult centres

The TSB has established a set of Catapult centres, which aim to encourage innovation and strengthen the UK's position in strategic industries. They provide physical centres which bring together businesses, scientists and engineers, to encourage ideas to be translated into new products and economic growth.

There are seven Catapult centres, of which one relates directly to the energy sector (the offshore renewable energy centre). Two new Catapult centres will be established

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187 See: https://www.gov.uk/innovation-funding-for-low-carbon-technologies-opportunities-for-bidders

by 2015, one of which will be on energy systems. This will focus on integration and control technologies required for future energy demand and supply.[188] Other Catapult centres relate to low-carbon electricity indirectly (e.g. the future cities and transport systems centres).

1.1.4 Funding from the Scottish Government

Scottish Government and Scottish Enterprise

The Scottish government contributes funding to some of the mechanisms described here (e.g. WRAP). In addition, it provides direct funding through the following:

- The Energy Technology Partnership (ETP); and
- Scottish Enterprise.

The ETP is an alliance of Scottish Universities, engaged in R&D and demonstration across a number of themes including renewable generation, networks and energy use in buildings. Scottish Enterprise is a body that aims to stimulate economic growth as well as exploiting low-carbon opportunities. It has provided funding to support the development of offshore renewables and smart grids. It also offers funding through the Scottish Energy Laboratory, which has a number of centres engaged in demonstration projects.

1.1.5 Publicly Funded Bodies

The Energy Technologies Institute (ETI)

The ETI aims to accelerate the technology developments required for the UK to meet its 2050 emissions targets. Rather than providing grants, the ETI makes targeted investments to for innovation between the basic R&D and commercial deployment stages. The ETI currently has a £100 million Smart Systems and Heat technology programme, which aims to design and demonstrate the first of its kind smart energy system in the UK. It is funded by BIS, TSB, DECC and the Engineering and Physical Sciences Research Council, as well as private sector members.

Waste and Resources Action Programme (WRAP)

WRAP focuses on encouraging recycling and creating a market for recycled materials in the UK. It focuses on food waste reduction, a resource efficient built environment, sustainable products, and waste as a resource. While much of its activity is not directly relevant to the electricity sector, it offers grants and capital loans for developing anaerobic digestion power generation; as well as the Waste Prevention Loan Fund (WPLF) which supports innovative and more resource efficient business in England.

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188 See: https://www.catapult.org.uk/two-new-catapults

The WPLF offers loans of £10,000 to £1 million. WRAP's Rural Community Energy Fund offers up to £150,000 of funding for rural communities to install renewable or low carbon energy facilities providing a legacy for the future benefit of the community. WRAP is funded by Defra and the Devolved Administrations (DAs).

1.1.6 Commercial and Other Funding Sources

Some funding is also available from other organisations, including commercial bodies and research councils. In general, funding from commercial sources is provided on a more *ad hoc* basis, and may provide less direct incentives for innovation, e.g. due to less transparency around decisions to award available funds. As a result, we have not focussed on these, but provide some examples to illustrate the types of funding available below.

EDF Pulse is an international innovation programme run by EDF, awarding funding and a communications campaign for innovation across five areas,[189] including awards for:

- electricity storage to a research team;
- smart living in the home to an entrepreneur;
- smart living in the area of mobility to an entrepreneur;
- smart living in the area of health to an entrepreneur; and
- access to electricity in emerging countries to a local electricity company.

The total funding is available is small relative to the funding sources described above, for example with €50,000available for each of the three home, mobility and health electricity and smart living awards. The winners of the funding will be chosen from a shortlist by public vote in March 2014.

The Carbon Trust sets up and invests in innovative low-carbon companies, including for example renewables manufacturers.[190] It also makes early stage investments to accelerate the commercialisation of low-carbon energy. Its funding therefore fits into the commercialisation stage of the innovation model in **Figure 1**.

The Research Councils UK Energy Programme is investing £625m in low-carbon energy. This funds research and skills development, some of which is relevant to networks and retail.[191]

[189] See: http://pulse.edf.com/en/edf-pulse-award/awards-presentation/?utm_medium=email&utm_source=UKERC&utm_campaign=3382708_NERN+Newsletter+29%2f11%2f2013&utm_content=art1&dm_i=UP4,20I44,C1TTHV,79OMM,1

[190] See: http://www.carbontrust.com/about-us/our-investments

[191] See: http://www.rcuk.ac.uk/research/xrcprogrammes/energy/Pages/home.aspx.

1.2 EU Funding Sources

EU sources of funding are available for a wider range of innovation types..

1.2.1 Horizon 2020

Horizon 2020 is the EU Framework Programme for Research and Innovation, running from 2014 to 2020. Horizon 2020 includes funding for projects to promote secure, clean and efficient energy.[192] Horizon 2020 will cover innovation-related activities from research to market, such as piloting, demonstration, test-beds, and support for public procurement and market uptake.

1.2.2 Eurogia 2020

Eurogia 2020 is committed to enhancing the competitiveness of European industry through the promotion of cross-border, market-oriented industrial innovation. It supports development of new technical solutions as well as facilitating deployment of existing technologies. Eurogia 2020 projects must show technical innovation for low-carbon energy technologies, and must have a strong market and exploitation orientation.

Eurogia 2020 does not provide funding; instead it awards projects a quality label. Funding is provided to participants within a certified project on a national basis, which in the UK is administered through DECC and the Technology Strategy Board. The maximum available grant per UK partner is £1m.[193]Bidders need to be an industrial company and must collaborate with an industry from another member state. Active participation by universities or research institutes is strongly encouraged.

1.2.3 Intelligent Energy Europe (IEE)

IEE supports projects putting the concept of 'intelligent energy' into practice. IEE supported renewable energy as well as energy-efficient buildings, transport, industry, and products. The programme ran from 2003 until 2013, with a total budget of €730 million. Its funding was available to EU Member States plus Norway, Iceland, Liechtenstein, Croatia and the Former Yugoslav Republic of Macedonia. Similarly to Horizon 2020, funding was available by responding to annual call for proposals which set priorities for funding.

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[192] The draft work programme in this area for 2014-2015 is available at: http://ec.europa.eu/research/horizon2020/pdf/work-programmes/secure_clean_and_efficient_energy_draft_work_programme.pdf#view=fit&pagemode=none.

[193] Further eligibility criteria are available at: http://www.eurogia.com/funding/countries/42-united-kingdom-.html?mn=40.

Paper 11 : 'How could electricity demand-side innovation serve the electricity customer in the longer term?' Frontier Economics & Sustainability First.

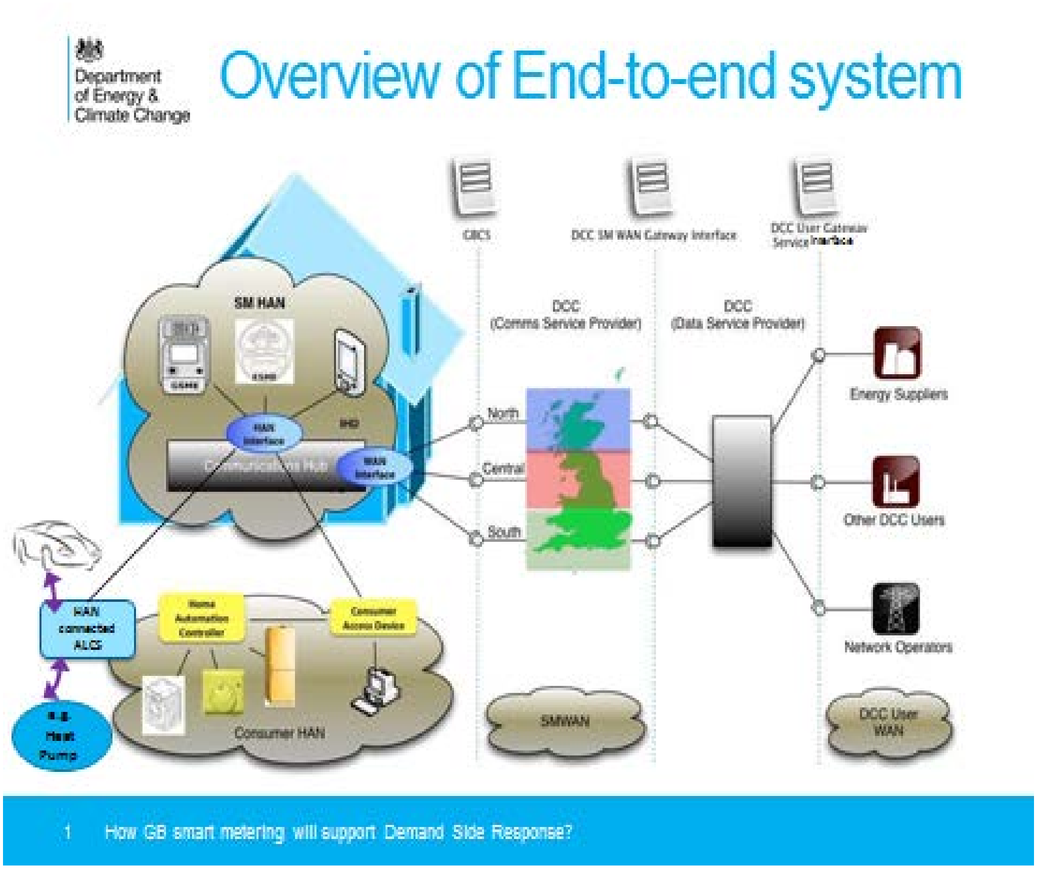
April 2014

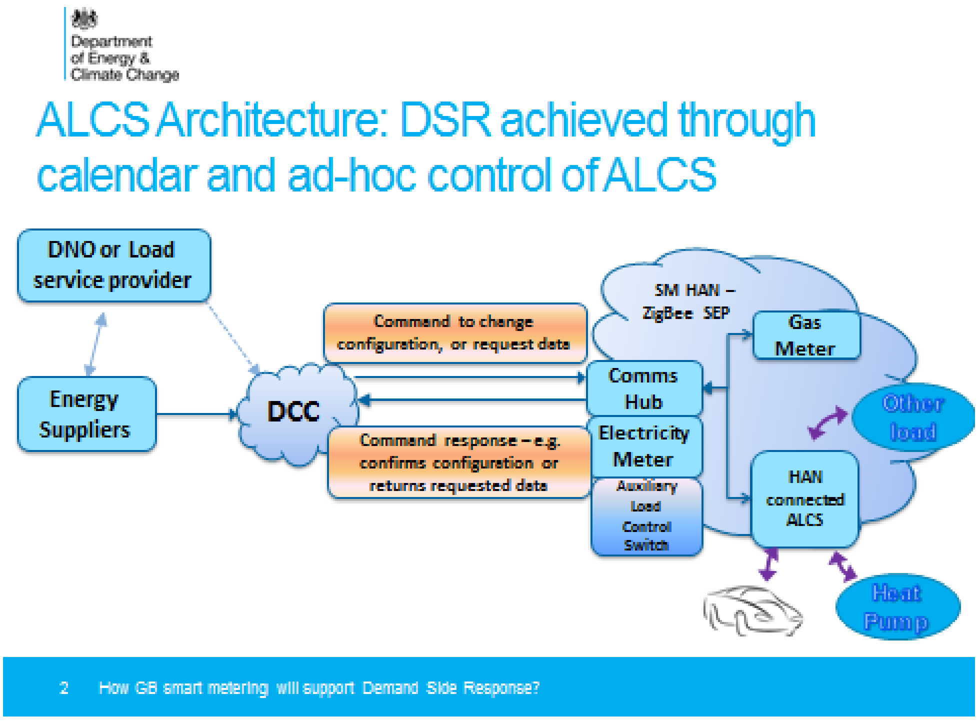
Annex 2 : Smart Meter Communications Arrangements for Automated Load Control

(See Chapter 4 on Automated Household Load Control).

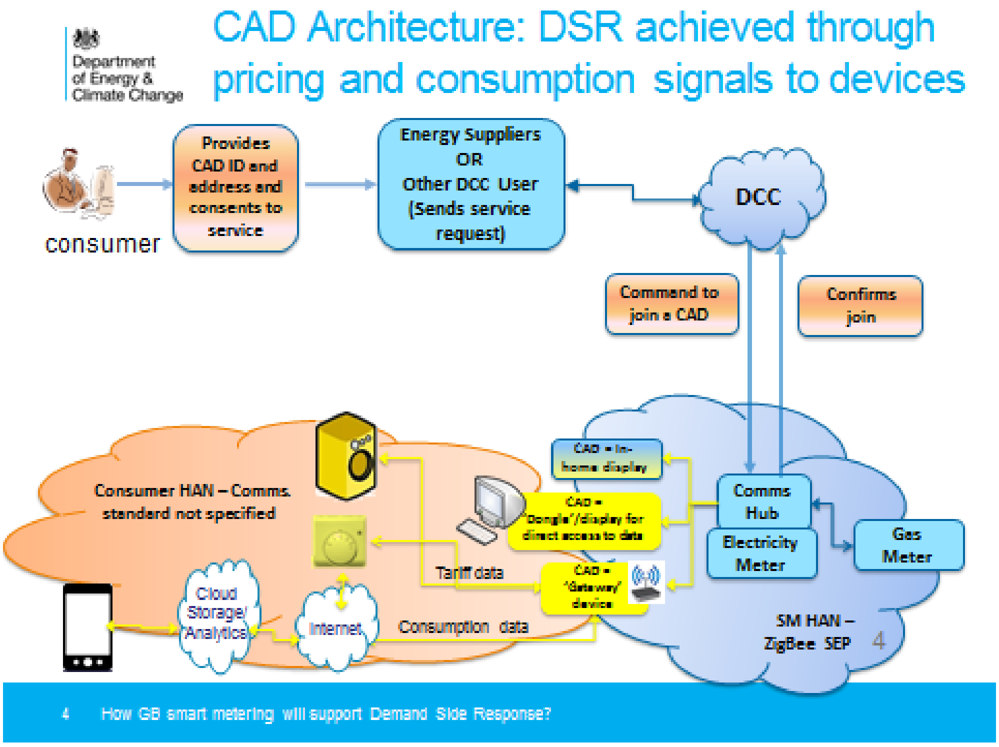
Extracted from : DECC presentation to DECC / Ofgem Smart Grid Forum Work Stream 6 on 'How GB Smart Metering Will Support Demand Side Response'. 18 March 2014.

The full slide-set will become available here : https://www.ofgem.gov.uk/electricity/distribution-networks/forums-seminars-and-working-groups/decc-ofgem-smart-grid-forum/work-stream-six.




Department of Energy & Climate Change
ALCS Architecture: DSR achieved through calendar and ad-hoc control of ALCS
DNO or Load service provider
Energy Suppliers
DCC
Command to change configuration, or request data
Command response – e.g. confirms configuration or returns requested data
SM HAN – ZigBee SEP
Comms Hub
Electricity Meter
Auxiliary Load Control Switch
Gas Meter
Other load
HAN connected ALCS
Heat Pump
2 How GB smart metering will support Demand Side Response?


Department of Energy & Climate Change
What is a CAD?
Any Device with a ZigBee SEP1.2 Interface and ZigBee features defined in GBCS
• In-home Displays;
• Gateways (eg ZigBee/WiFi)
• Smart Appliances;
• Smart Energy Hubs/gateways;
• Laptop dongles;
• Thermostats
3 How GB smart metering will support Demand Side Response?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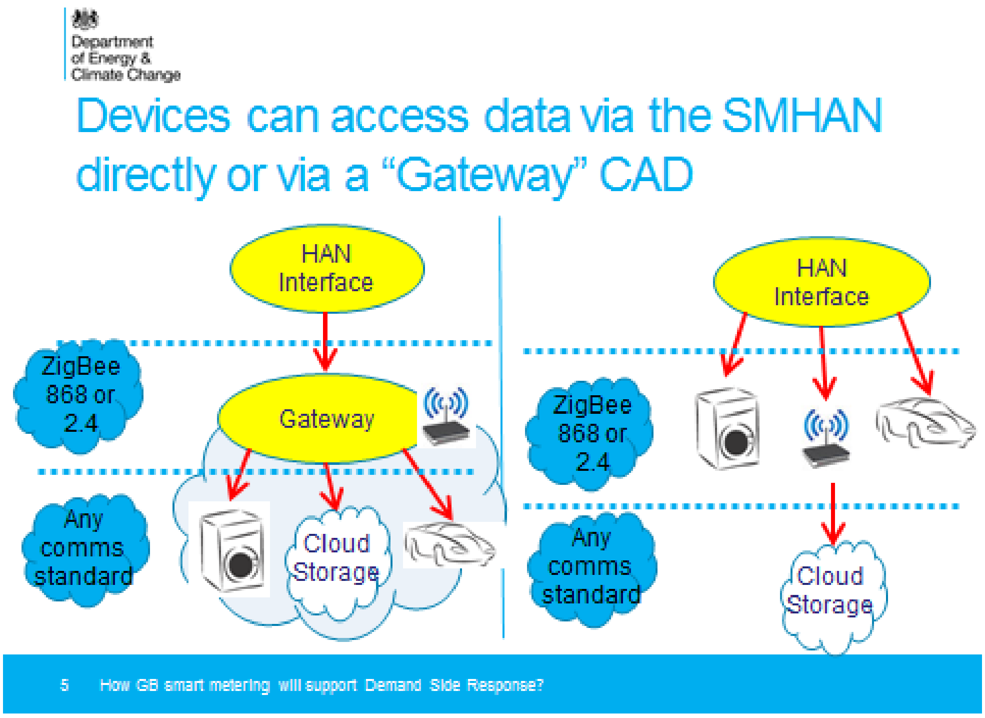
CAD Architecture: DSR achieved through pricing and consumption signals to devices
consumer
Provides CAD ID and address and consents to service
Energy Suppliers OR Other DCC User (Sends service request)
DCC
Command to join a CAD
Confirms join
Consumer HAN – Comms. standard not specified
CAD = In-home display
CAD = 'Dongle'/display for direct access to data
CAD = 'Gateway' device
Comms Hub
Electricity Meter
Gas Meter
Tariff data
Consumption data
Cloud Storage/ Analytics
Internet
SM HAN – ZigBee SEP
4
4 How GB smart metering will support Demand Side Response?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Devices can access data via the SMHAN directly or via a "Gateway" CAD
HAN Interface
ZigBee 868 or 2.4
Gateway
Any comms standard
Cloud Storage
HAN Interface
ZigBee 868 or 2.4
Any comms standard
Cloud Storage
5 How GB smart metering will support Demand Side Response?

Sustainability First