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## **Call for evidence on electricity demand-side measures**

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We welcome the opportunity to submit evidence to the inquiry. As the inquiry particulars [set out](#), reduction in demand can be temporary (known as demand-side response (DSR)) or permanent (known as electricity demand reduction (EDR)). We use this nomenclature throughout this response.

We have primarily directed our responses to three main questions set out in the terms of reference.

Overall, our view is that the combination of the demand side measures put together and/or executed by the Government and Ofgem did not place enough attention on (i) design which should have led to successful implementation of policies; (ii) the flexibility needs of an electricity system with a high proportion of variable power (which whilst not the situation now should become so by 2020); and (iii) the need for complementarity with wider energy policy goals.

We see the demand side as being important for two main reasons:

- Firstly, an energy system transformation based on selling will be (i) much more expensive to transform to the system level rather than one which uses energy as efficiently as possible; (ii) much less desirable from a resource perspective (i.e. much more resource is needed to make that system); and (iii) much more expensive at the household bill level. Arguably, a central focus of Energy Policy should be on helping customers to consume less.
- Secondly, it is becoming clear within electricity systems that increasing levels of variable power, while reducing carbon, also lead to a number of challenges related to system operation; profitability for fossil generators; potential investment concerns for fossil fuel plants (and therefore a dimension of ensuring security of supply); and the need for more flexible demand.

In both cases, the demand side is a vital, economic dimension of an efficient, affordable future energy system. However, there are minimal incentives to reduce energy relative to supplying it or to make it more flexible (Mitchell 2014).

## **How can the Government ensure that new technology which facilitates DSR is deployed in a timely manner, now and in future, to reduce peak demand for electricity?**

### **Current DSR**

1. Currently, demand side response (DSR) in the Great Britain (GB) electricity system is provided by some large industrial, commercial and public consumers, sometimes via aggregators, along with a basic form of demand management in Economy 7 rates for electrical heating in the residential sector. Both forms of DSR rely on existing technology.
2. DSR is contracted by the GB System Operator (i.e. National Grid) mainly for ancillary services. Demand response is found mainly in the short-term operating reserve (STOR), commercial (i.e. non-mandatory) frequency response markets, and in Triad avoidance, and is of the order of 2-3GW in total.
3. The overall contribution of DSR in the GB ancillary energy services markets thus remains quite small. Experience elsewhere, for example in the US (e.g. Hurley et al 2013) where demand response capacity approaches 10% of peak demand (an equivalent to 5-6GW in GB), suggests that there is further unrealised resource.
4. However, this is not due to technological barriers, since actual and potential participating industrial, commercial and public actors already have half-hourly metering. Energy-intensive industries in the UK tend to argue that manufacturing processes are not very interruptible and so the technical potential of I&C DSR is not large (e.g. British Ceramic Confederation 2009: 2).
5. The only form of demand response in the residential household sector is the Economy 7 system, designed to shift peak time electrical demand for space heating to the night, in order to increase night time demand to match the output of nuclear power stations. In 2011, around 5 million households were on Economy 7 tariffs, using 29 TWh of electricity. According to Elexon (2012), just over two million customers have their electrical storage and immersion water heating controlled remotely by radio teleswitching, although only a minority of these have dynamic real-time response. Total annual switched energy is 1.9 TWh, or around 0.5% of total electricity supplied. Again, this system uses existing technology.

### **Future DSR**

6. Future DSR needs will be driven (1) by the potential addition of very large peak electrical loads through the electrification of heating (Wilson et al 2013) and transport (Pieltain Fernandez et al 2011), which will far exceed the capacity of current distribution networks, especially on their low voltage parts. Some reinforcement will be inevitable, but the ability to shift demand so as to limit peaks could substantially reduce the extent and cost of that reinforcement (e.g. Strbac et al 2010); and (2) an increasing proportion of electricity from variable sources such as wind and solar. As the proportion of supply becomes less certain, so the economic value of making demand more certain increases.
7. A smarter electricity infrastructure will be needed to facilitate such DSR, which in GB has been institutionally separated into smart meters and smart grids. The technical specification of smart meters has now been completed and roll-out is commencing, so the main issue is now the delivery of smart grids.

8. The development of smarter distribution grids will involve research, development, demonstration and deployment of a range of technologies across a number of areas (Smart Grid Forum 2011). Programmes for technological R&D in electricity distribution were introduced by Ofgem in DPCR4 (2005) in the form of the Innovation Funding Incentive (IFI) and Registered Power Zones (RPZs). In DPCR5, as the Low Carbon Network Fund (LCNF), this approach was substantially expanded, and includes demonstration of new technologies in real network situations.
9. The next round of electricity distribution regulation due to run from 2015 to 2023, i.e. RIIO-ED1, will replace the LCNF with an ‘innovation stimulus’ (Ofgem 2013b: 97). This consists of a Network Innovation Competition (NIC), in which companies bid for funds for large scale projects, similarly to the LCNF, and a use-it-or-lose-it Network Innovation Allowance (NIA) for smaller projects, of up to between 0.5 and 1 % of revenues. The NIC is resourced at around £90 million a year for the first two years of RIIO-ED1, roughly the same in real terms as the LCNF. Other actors in the electricity industry which have signed up to the distribution licence (e.g. suppliers, generators) can also apply.
10. In 2010, DECC and Ofgem also set up the Smart Grid Forum (SGF), which brings together actors from the electricity and ICT industries, which amongst other things is working to coordinate agreement on interoperability, smart grid architectures and requirements for smart grid functionality.
11. The development of the R&D mechanisms within network regulation and the formation of the SGF have been very important for catalysing the development of smart grid technologies. The key issue for technological development is now whether, and how, trials from the LCNF (and in future the NIC/NIA) will feed into business-as-usual network planning and operation, under the incentive regime created by network regulation.
12. Innovation involves not only research on, and development of, new technologies and practices and their demonstration in pilots, but also their successful commercial deployment in network situations where they can be assessed and tested for a number of years in real-world conditions (Smart Grid Forum 2014). It is thus more about eventual outcomes than projects per se.
13. As the chief executive of one of the DNOs put it in a previous Select Committee enquiry: “Most of the things that will need to change in order for the distribution networks to do the kinds of things to which you have referred already exist; it is not technology that is not already out there, but it is just not applied in the public networks in this country. We do not need to invent things that do not exist but we need to apply them and really understand how they would work. We are talking here about the public electricity supply network which needs to be absolutely safe. We need to understand how it would operate in reality rather than in a laboratory or test case.” (Phil Jones, Northern Powergrid, in ECC 2010: Ev55)
14. RIIO-ED1 is intended to facilitate the adoption of innovative approaches to network planning and operation, through a number of changes from the previous RPI-X regulation (Askew 2013). These include:
  - Longer price control period – from 5 to 8 years, explicitly in order to allow longer payback periods for more innovative investments that might otherwise be rejected under a five year period.
  - The output incentives associated with performance targets for network quality and customer satisfaction have been strengthened compared with recent RPI-X regulation.

- Instead of additions to the DNOs regulated asset value (RAV) being made on the basis of actual capital expenditure, they are now deemed to be 70% of ex ante agreed total expenditure. In principle, this means that the incentive to skew actual spend towards capex, which might militate against smarter network solutions, is removed.
  - There is both an incentive for companies to specify how they will roll out learning from current R&D into business-as-usual practice, and a mechanism to help pay for that roll out.
  - In order to qualify for the fast-track acceptance of business plans (a considerable incentive given the financial savings and reputational gain involved), DNOs have to set out an innovation strategy in their business plans, including evidence of how they will incorporate learning from LCNF and other innovation trials into business-as-usual. Ofgem's guidance for what the innovation strategy should address refers companies to work by the Smart Grid Forum (see below) on particular functionalities to be achieved by 2020 and 2030 (SGF 2011).
15. It remains to be seen whether these changes under RIIO-ED1 will actually lead to the deployment of new smarter technologies, developed in trials, in distribution networks, especially at the low voltage level. DNO business plans suggest that investments in smart grid technologies in the ED1 period will be of the order of 1% of total expenditure. This does not represent a sea-change in views about where the future investment should be; rather it still remains marginal. One reason for this may be because a number of potential risks faced by companies which arise out of the regulatory framework still remain (see also Ward et al 2012a: 54). This presents some challenges, given that DNOs have historically been risk-averse.
  16. First, at the micro-level, individual technologies may fail in real-world network situations over longer periods of time (e.g. 3-5 years) even if they have worked well in trials. This was initially the case with new plastics-based insulation for underground cables in the 1970s, for example. These risks expose DNOs to the possibility that these failures would lead to a reduction in reliability, safety and other aspects of network performance for which they would be penalised either within output incentive schemes or through fines for failing to meet licence conditions. Since output incentives under RIIO are stronger and more extensive than under RPI-X, these risks may have actually been accentuated.
  17. Second, even though they have trialed a technology, companies (and the regulator) will not know fully how much these will cost in real-world network situations, especially because mature supply chains for equipment in many cases do not exist, and will not exist until demand scales up. Within the context of incentive regulation, if companies underestimate these costs in a price-control settlement, they will be penalised.
  18. At present, the approach of both DNOs and Ofgem appears to be that such risks will be limited, because the scale up of low carbon technologies such as heat pumps and electric vehicles will be relatively slow, with no major growth before 2020: "The take up of low carbon technologies is predicted to increase significantly during RIIO-ED2 and RIIO-ED3...The RIIO-ED1 period represents an opportunity to start to deploy smart grid solutions and get prepared for the more radical network changes that may be required in the future" (Ofgem 2013a: 17).
  19. Ofgem has instructed DNOs to form 'best views' on the take up and clustering of low carbon technologies in their network areas over the next 8 years, based in part on engagement with users of networks and part on DECC's own projections in the Carbon Plan. However, it is inherently difficult to make such projections, not least because actual take-up will be sensitive not only to consumer preferences, but also to future UK policy and costs, the latter of which may in turn be sensitive to the policies of other countries. There is a real risk that 'best views' (which tend to the conservative side of the Carbon Plan scenarios) underestimate the growth of new

loads, perhaps especially electric vehicle charging, because of these factors. This is dramatically illustrated in the case of solar PV, where scenarios for growth constructed in 2011 already vastly underestimate the expansion of installed capacity because of the effects of the feed-in tariff and module cost reductions. Some distribution networks are already facing voltage management challenges arising from this growth. If there are changes in government policy, or electric vehicle battery costs fall more quickly than anticipated, scenarios for other low carbon technologies could easily be overtaken by events.

20. Ofgem is attempting to limit the effects of uncertainty on DNOs through a “re-opener” that allows the revenue cap to be adjusted when actual load-related expenditure (including on low carbon technologies) diverges from forecasts by more than 20%. There will also be a mid-term review of RIIO-ED1 which may also reset regulatory parameters if actual growth and projected growth have diverged.
21. Since privatisation the UK approach to network regulation has been explicitly designed so as to shift some risk from consumers to network companies. This approach may be appropriate during periods of relatively slow and predictable growth in loads and rates of low technological innovation, (although in practice network companies have mostly found it easy to outperform on their regulatory contract). However, it is not as clear that it works well for a period of transformation, because the uncertainty involved makes it more likely to lead to under-investment.
22. If it is accepted that we are embarking on such a period, then alternative approaches should be considered. These may include:
  - Greater coordination and commitment from the Government more widely in the deployment of electric vehicles and heat pumps, allowing a more accurate assessment of the scale of risk in the deployment of smart grid technologies
  - Absorbing more of the deployment risk in particular areas, related to the roll-out of technologies trialled in the LCNF/NIC/NIA. This could be done by expanding the role of the proposed Innovation Roll-Out Mechanism (which is primarily designed to support the roll out of new technologies and approaches where benefits for the DNO are not high enough for it to do so on its own, or where risks are too high). Such a mechanism would be time-limited. It essentially extends the principle underlying the LCNF to the deployment phase of technological innovation. This approach would also benefit from the development of stronger engineering capacity within Ofgem and DECC, to ensure that the Government and regulator understand the nature of technology change, and to limit the effects of any rent-seeking by DNOs.
23. Finally, there are risks arising from potential problems with interoperability if DNOs adopt technologies and approaches from LCNF trials without any overall coordination by a ‘system architect’ (see also Shaw et al 2012, Skillings 2010, Sansom 2010). The risk here is that particular assets may become stranded if they do not conform to future standards or are not interoperable with what become dominant technologies. The Smart Grid Forum is discussing the potential of smart grid architecture models, but is not yet actively providing such coordination.
24. It is not necessarily that case that Government has to take on a direct coordinating role to overcome problems of interoperability, but in the absence of the distribution and ICT industries developing that role, it should give clear direction that they should do so.

**Are the Government's and Ofgem's current proposals for incentivising the development of demand reduction measures enough to ensure the potential energy savings outlined in the 2012 Energy Efficiency Strategy are achieved?**

25. The 2012 Energy Efficiency Strategy offers a projected saving of 163TWh of energy by 2020, as compared to a business-as-usual case, and states that even greater savings of 196TWh are cost-effectively achievable. In his foreword the Minister Ed Davey states his wish for Britain to come as close to that figure as possible.
26. It is not clear what proportion of these savings is intended to be made from each sector of the economy, or through reduction of which energy carrier. However, given that in 2012 electricity consumption made up 18.5% of total final energy consumption (including transport fuels) (DECC 2013), and given the nascent nature of technologies to make significant reductions in the transport sector (the sector responsible for the single largest portion of demand), it is reasonable to assume that electricity demand reduction may be expected to be responsible for a significant proportion of the energy savings between now and 2020.
27. Given that domestic electricity demand accounted for approximately 36% of all electricity demand in 2012 (Calculated from figures in DECC 2013), it may again be assumed that the domestic sector may offer a significant potential for this demand reduction. However, domestic sector electricity demand reduction policies appear severely limited in their number and scope.
28. The current policies in place that affect domestic sector electricity consumption:
29. **Product Policy:** The European Ecodesign policies apply to a wide range of consumer products, and the considerable benefits that these policies have brought through reduced consumption are widely documented. The government has carried out forecasts for the cost-effective potential reductions in demand from product policy. For example it was suggested that cost effective policies could reduce energy consumption from consumer electronics by 5.28TWh by 2020 against a business-as-usual case (DEFRA 2009). However progress on this front cannot be monitored, owing to a lack of up-to-date data, an issue highlighted by the CCC in its Carbon Budget Progress Report to Parliament in both 2012 and 2013 (CCC 2012; CCC 2013). The most recently available figures (2010) showed penetration of high efficiency appliances to be lower than expected, and this may give cause for concern. Given the heavy burden that product policy carries with regard to ensuring domestic electricity demand reduction, we believe it is essential that this monitoring be reintroduced and appropriate steps taken if lower-than-expected trends are found to be continuing.
30. **Green Deal and Energy Company Obligation:** These are severely limited in their scope to support electricity demand reduction, in that they almost exclusively offer electricity reductions in dwellings whose primary heating source is electricity – this is less than 10% of the British housing stock (Consumer Focus 2011). Given this low figure, the challenges in uptake experienced by the Green Deal, and the recent extended deadline for the Energy Company Obligation, it seems unlikely that these policies will lead to significant electricity demand reductions.
31. **Low Carbon Network Fund (LCNF):** This fund allows distribution network operators (DNOs) space to innovate. This includes, although is not limited to, space to run trials to reduce the electricity demand of the customers attached to their networks. It is unclear what effect the LCNF is likely to play in reducing overall electricity demand to 2020. Where we wholeheartedly support encouraging innovation and exploring roles in demand reduction for other institutions,

such trials are currently limited in scale and therefore may not achieve significant savings en route to 2020.

32. **Smart Meters:** Smart meters with in-home displays (IHDs) may offer greater transparency of energy demand, which may in turn lead to reduced consumption, through increased awareness of energy behaviours. However the degree to which this may lead to overall reduced consumption is not clear. An early review (Darby 2006) suggested that savings from indirect feedback (i.e. bills) range from 0-10% and savings from direct feedback (e.g. real-time IHD) could lead to energy savings of 5-15%. A later review suggested UK savings likely to be at lower end of these ranges (Aecom 2011). The government funded 2007-2011 Energy Demand research project involving 50k trial households and 10k control households showed that smart meters appear to have a small effect (2-3%) on demand for gas and electricity, either on their own or combined with other interventions. These appeared to be persistent across time. Real-time IHDs reduced demand for electricity in the range of 2-4%. Time-of-use tariffs may potentially offer fuel poor options to reduce bills, but if their demand is inflexible, may worsen the problem (Darby 2012). Therefore smart meters should not be relied upon to provide significant levels of demand reduction.
33. **Throughput incentives on networks:** GB networks do have certain incentives on them which are intended to make them indifferent to the amount of kWhs which pass across their networks. However, it is generally argued that because the regulatory asset value will be related to peak capacity, there is still an underlying incentive to sell rather than to save. Twenty three of the 50 States in the US (RAP 2011) have 'decoupling' policies in place which are intended to make them indifferent in reality to selling or saving by providing a 'balancing' source of revenue to the networks for any saved energy.
34. Overall, it is clear that the policies in place to address domestic electricity demand are at best severely limited. The most prominent policy (product policy) is relied heavily upon, but goes unmonitored. Given the prominence of the sector, the increasing trend for consumer electronics, and the fact that any black/brownouts that might be experienced as a result of the 'capacity crunch' are likely to be a result of a spike in demand from the domestic sector, we believe that much greater attention must be paid to domestic electricity demand reduction.

### **How will the Government's latest detailed design proposals for the forthcoming CM help to develop an enduring regime for demand reduction measures?**

35. The latest report from the Government (DECC 2014) on how much capacity it intends to procure for the CM, and from where (i.e. including the demand side or not) does not appear to complement the demand side sufficiently, nor complement the wider aims of British energy policy – i.e. promoting the most affordable, low carbon and secure energy system rather than simply focus on cheapness. As more and more low carbon and variable renewable power comes on the electricity system, so the supply curve shifts to the right and there is less and less market demand to be met by fossil generation. The availability of flexible capacity (including the demand side) and suitable ancillary services becomes more important in systems with high proportions of variable power in order to complement the uncertain output. Providing the 'right' type of flexible capabilities for a secure electricity system (Gottstein and Skillings, 2012; Hogan, 2012; Baker and Gottstein, 2013; Keay-Bright, 2013, Mitchell, 2014) should become more important and be valued more highly. This is not the case of the current CM design which seems likely in practice to support the 'old' system that British energy policy is trying to move on from.

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## References

Aecom Building Engineering (2011a) *Review of the literature on interventions used in EDRP*, Appendix C, EDRP: Final Analysis

Askew, M. (2013) 'Incentivising deployment of smart grids' Presentation to Clean power and smart grids conference, <http://www.cir-strategy.com/uploads/sgcp13askew.pdf>

P Baker and M Gottstein, 2013, Capacity Markets and European Market Coupling – can they co-exist? Discussion Paper, RAP, March 2013; [www.raponline.org/document/download/id/6386](http://www.raponline.org/document/download/id/6386)

British Ceramic Confederation (2009) Response to Ofgem – Project Discovery Consultation, <https://www.ofgem.gov.uk/ofgem-publications/40302/british-ceramic-confederation.pdf>

CCC (2012) Meeting Carbon Budgets – 2012 Progress Report to Parliament  
[http://www.theccc.org.uk/wp-content/uploads/2012/06/1585\\_CCC\\_Progress-Rep-2012\\_bookmarked\\_1\\_KD.pdf](http://www.theccc.org.uk/wp-content/uploads/2012/06/1585_CCC_Progress-Rep-2012_bookmarked_1_KD.pdf)

CCC (2013) Meeting Carbon Budgets – 2013 Progress Report to Parliament  
[http://www.theccc.org.uk/wp-content/uploads/2013/06/CCC-Prog-Rep-Book\\_singles\\_web\\_1.pdf](http://www.theccc.org.uk/wp-content/uploads/2013/06/CCC-Prog-Rep-Book_singles_web_1.pdf)

Consumer Focus (2011) Off-gas consumers: Information on households without mains gas heating  
<http://www.consumerfocus.org.uk/files/2011/10/Off-gas-consumers.pdf>

Darby, S. (2012) 'Metering: EU policy and implications for fuel poor households' *Energy Policy* 49, pp. 98-106

DECC (2014) EMR Panel of Technical Experts' Final Report on National Grid's Electricity Capacity Report  
[https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/324976/EMR\\_Panel\\_s\\_Final\\_Report\\_on\\_National\\_Grid\\_s\\_ECR.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/324976/EMR_Panel_s_Final_Report_on_National_Grid_s_ECR.pdf)

DECC (2013) DUKES  
[https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/279523/DUKES\\_2013\\_published\\_version.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/279523/DUKES_2013_published_version.pdf)

DEFRA (2009) Saving Energy Through Better Products and Appliances  
<http://archive.defra.gov.uk/environment/economy/documents/energy-products-1209.pdf>



EA Technology (2012) Assessing the impact of low carbon technologies on Great Britain's power distribution networks Report prepared for the Energy Networks Association on behalf of the Smart Grids Forum, Workstream 3, Available at: <https://www.ofgem.gov.uk/ofgem-publications/56824/ws3-ph2-report.pdf>

Energy and Climate Change Committee (2010) The future of Britain's electricity networks Second report of session 2009-10, Volume II, HC194-1

Elexon (2012) Dynamic Switching Roadmap, PSRG22/01, [http://www.elexon.co.uk/wp-content/uploads/2012/07/PSRG22\\_01\\_dynamic\\_switching\\_roadmap.pdf](http://www.elexon.co.uk/wp-content/uploads/2012/07/PSRG22_01_dynamic_switching_roadmap.pdf)

M.Gottstein and S.Skillings (2012) Beyond Capacity Markets – delivering capability resources to Europe's Decarbonised Power System,; [www.raponline.org/document/download/id/4854](http://www.raponline.org/document/download/id/4854)

M Hogan (2012) What Lies Beyond Capacity Markets? Delivering Least Cost Reliability Under the New Resource Paradigm, regulatory Assistance Project, <http://www.raponline.org/document/download/id/6041>

Hurley, D., Peterson, P. and Whited, M. (2013) Demand response as a power system resource: Program designs, performance and lessons learned in the United States, Synapse Energy Economics for RAP, <http://www.synapse-energy.com/Downloads/SynapseReport.2013-03.RAP.US-Demand-Response.12-080.pdf>

S. Keay Bright (2013) Capacity Mechanisms for Power System Reliability – why the traditional approach will fail to keep the lights on at least cost and can work at cross-purposes with carbon reduction goals, <http://www.raponline.org/search/site/?q=keay-bright%202013>

Martin, A. (2013) Distributed generation and demand response: Enablers and blockers Presentation to UKERC/Sustainability First workshop on GB Electricity Demand: Realising the Response, May 2013, [http://www.ukerc.ac.uk/support/0513\\_MP\\_GBElectricity](http://www.ukerc.ac.uk/support/0513_MP_GBElectricity)

Mitchell, C. (2014) Change and Inertia in the UK Energy System – getting our institutions and governance right. <http://projects.exeter.ac.uk/igov/working-paper-change-and-inertia-in-the-uk-energy-system/>

National Grid (2013) STOR Market Information Report: Tender Round 21, <http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=25411>

Ofgem (2013a) Strategy decision for the RIIO-ED1 electricity distribution price control Ofgem: London

Ofgem (2013b) Strategy decision for the RIIO-ED1 electricity distribution price control: Outputs, incentives and innovation Ofgem: London

Pieltain Fernandez, L., Gomez, T., Cossent, R., Mateo Domingo, C., and Frias, P. (2011) 'Assessment of the impact of plug-in electric vehicles on distribution networks' Power Syst. IEEE Trans. 26 (1), 206e213

RAP (2011) Revenue Regulation and Decoupling: A Guide to Theory and Application. [file:///C:/Users/rdh208/Downloads/RAP\\_RevenueRegulationandDecoupling\\_2011\\_04.pdf](file:///C:/Users/rdh208/Downloads/RAP_RevenueRegulationandDecoupling_2011_04.pdf)

Sansom, R. (2010) 'RPI-X@20 emerging thinking on "A new regulatory framework for energy networks' Presentation at Ofgem academic RPI-X@20 workshop, March 2010, available at: <http://www.ofgem.gov.uk/Networks/rpix20/Workshops/Documents1/Academic%20workshop%20Robert%20Sansom%20slides.pdf>

Shaw, R., Attree, M. and Jackson, T. (2010) Developing electricity distribution networks and their regulation to support sustainable energy. Energy Policy 38, pp. 5927-37

Skillings, S. (2010) A road map to deliver smart grid in the UK London: E3G

Smart Grid Forum (2011) Developing networks for low carbon: The building blocks for Britain's smart grids Work Stream 3 report <https://www.ofgem.gov.uk/ofgem-publications/56828/smart-grid-forum-workstream-3-report-071011-master.pdf>

Smart Grid Forum (2014) Smart Grid Vision and Routemap London: Ofgem/DECC, [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/285417/Smart\\_Grid\\_Vision\\_and\\_RoutemapFINAL.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/285417/Smart_Grid_Vision_and_RoutemapFINAL.pdf)

Strbac, G., Gan, C. K., Aunedi, M., Stanojevic, V., Djapic, P., Dejvises, J., Mancarella, P., Hawkes, A., Pudjianto, D. Le Vine, S., Polak, J. Openshaw, D., Burns, S., West, P., Brogden, D., Creighton, A., and Claxton, A. (2010) Benefits of Advanced Smart Metering for Demand Response based Control of Distribution Networks London: Energy Networks Association, Available at: [http://www.energynetworks.org/modx/assets/files/electricity/futures/smart\\_meters/Smart\\_Metering\\_Benefits\\_Summary\\_ENASEDGImperial\\_100409.pdf](http://www.energynetworks.org/modx/assets/files/electricity/futures/smart_meters/Smart_Metering_Benefits_Summary_ENASEDGImperial_100409.pdf)

Ward, J., Owen, G. and Pooley, M. (2012a) The electricity demand-side and wider policy Paper 5, GB Electricity Demand – Realising the Resource, Sustainability First, London, <http://www.sustainabilityfirst.org.uk/docs/2012/Sustainability%20First%20-%20GB%20Electricity%20Demand%20-%20Paper%205%20-%20Electricity%20Demand%20Side%20&%20Wider%20Energy%20Policy-Nov%202012.pdf>

Ward, J., Pooley, M. and Owen, G. (2012b) What demand-side services can provide value to the electricity sector? Paper 4, GB Electricity Demand – Realising the Resource, Sustainability First, London, <http://www.sustainabilityfirst.org.uk/docs/2012/Sustainability%20First%20-%20GB%20Electricity%20Demand%20-%20Paper%204%20-%20What%20demand%20side%20services%20can%20provide%20value%20to%20the%20electricity%20sector%20-June%202012.pdf>

Wilson, I. A. G., Rennie, A. J. R., Ding, Y., Eames, P. C., Hall, P. J., and Kelly, N. J. (2013) Historical daily gas and electrical flows through Great Britain's transmission networks and the decarbonisation of domestic heat. Energy Policy 61, pp. 301-305