Domestic and SME tariff development for the Customer-Led Network Revolution

A REPORT PREPARED FOR NORTHERN POWERGRID

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Executive Summary

Northern Powergrid's Customer-Led Network Revolution (CLNR) project is testing demand side response solutions across a range of customer groups. This report describes the methodology we have used to develop the domestic and SME tariffs and presents the resulting tariffs that will be trialled. The methodology and tariff propositions have been developed in collaboration with Northern Powergrid and British Gas.

Introduction

The CLNR received funding under Ofgem's Low Carbon Networks Fund in 2010. It aims to provide knowledge and experience on the deployment of network response and demand response technologies at distribution network level. This report focuses on the part of the project which looks at customer-side innovations, in particular considering:

- the extent to which customers are flexible in their load and generation; and
- the cost of this flexibility.

The trial aims to test three tariff types across domestic and small business (SME) customer groups, with a particular focus on customers holding low-carbon technologies such as electric vehicles and heat pumps. The three tariff types are as follows.

- **Time of Use** - a static time of use tariff leaving customers with total discretion over how they respond.
- **Restricted Hours** - a static time of use tariff with an additional automated load switching facility which runs key loads outside of peak periods as a default, but allows customers to override this default if they wish.
- **Direct Control –** a proposition which allows certain loads to be occasionally interrupted through external dynamic signals and which does not allow customers to override the interruptions.

A technical solution enabling customers with solar photovoltaic (PV) panels to use the power they generate within the home is also included in the trial.

Principles and practical issues

To best contribute to the aims of the CLNR, each proposition included in the trial should:

- be relevant;
- provide new and robust learning; and
- be capable of being practically implemented.

Relevance

Each tariff proposition should focus on interventions that could be usefully implemented in the future. Specifically, each proposition should focus on those interventions which are likely to create value (by reducing electricity system costs) and be commercially viable in the period around 2020.

The need for tariff propositions to be relevant meant that to design the Time of Use and Restricted Hours tariffs, an understanding of the costs of supplying electricity by time of day in 2020 had to be developed. To develop the Direct Control tariffs, an estimate of the value of interrupting supply to customers in 2020 was required.

Provision of new and robust learning

The trial should provide learning that is additional to the learning provided by existing trials. It should focus on two types of question:

- how attractive propositions are likely to be to customers, i.e. whether customers are likely to take up a given proposition; and
- how customers behave once they have taken up a tariff.

The trial should also add to what has already been learnt from the results of recent trials.

Practicality

The test cells should focus on interventions that it will be possible to trial. In particular, the following are important constraints.

- The trial relies on sufficient customers being available with low carbon technologies such as electric vehicles, heat pumps and solar PV.
- The trial is limited by the current information technology and systems that the project partners have in place. This means that some tariff propositions which are likely to be commercially viable in 2020 may not be feasible to trial at this stage.

These principles inform the development of tariffs and prioritisation between test cells.

The role of demand side response

Demand side response (DSR) can reduce costs across the electricity system by allowing investment in new capacity to be deferred. The role of DSR is likely to increase to 2020 as low-carbon technologies such as electric vehicles and heat pumps both increase the size of daily peaks in demand, and increase the proportion of demand that can be flexible.

The contribution of static time of use tariffs

Static time of use tariffs which reflect the underlying electricity system costs by time of day, can help reduce system costs by providing incentives to customers to shift demand to times when system costs are lower. These types of tariffs underlie the Time of Use and Restricted Hours propositions in the CLNR.

The impact of increased penetration of intermittent generation technologies (such as wind generation) will eventually mean that dynamic signals may be required. However, our analysis suggests that in 2020, the profile of electricity generation cost across the day should continue to be closely related to demand, that the demand curve will have a similar shape to the current one, and that peaks in generation costs and demand costs will continue to coincide. This implies that static time of use tariffs will still be valuable and relevant in 2020.

The contribution of direct load control tariffs

Direct load control tariffs, such as the Direct Control proposition included in this trial, allow occasional on-demand reductions in peak demand, and could help to reduce costs at HV level. This is because reinforcement of the high voltage (HV) network can be deferred if DSR can be called at times of network outage, instead of reliance having to be put on the back-up network.

Customer numbers

Some changes to the propositions included in the bid are required because fewer customers with low-carbon technologies are likely to be available than was expected at the time of the original bid.

Table 1 compares the allocation in the original bid to the allocation now to be included in the trial.

Table 1. Summary of test cells include in the bid

	Test cell no.	Description	Customer numbers in original bid	Customer numbers
General load (white goods and immersion heaters)	9	Pure Time of use	600 domestic, 150 SME	No change
	10	Restricted Hours	600 domestic, 150 SME	Smart white goods will be subsidised for 150 domestic customers. Recruitment of an additional 600 customers with electric hot water heating is planned (300 per test cell)
	11	Direct Control	600 domestic, 150 SME	
Customers with heat pumps	12	Pure Time of use	600 domestic	400 customers with heat pumps (without storage) may be available if DECC funding is agreed
	13	Restricted Hours	150 domestic	100 customers with heat pumps with storage will be spread across the Restricted Hours and Direct Control test cells
	14	Direct Control	150 domestic	
Customers with electric vehicles	15	Pure Time of use	50 domestic	Severe restrictions on customer numbers are likely. Test cell 15 and 17 will be excluded from the trial and a time of use tariff will be trialled on electric vehicle customers in LO1 instead.
	16	Restricted Hours	50 domestic	
	17	Direct Control	50 domestic	
Customers with solar PV	20	Within premises balancing	600 domestic	The current feed-in tariff regime limits the learning from this cell so it will be reduced in size to 300 - 150 customers with automatic within premises balancing with hot water heating and 150 with manual within premises balancing (with an In Home Display).

Source: Optional Appendices: Customer Led Network Revolution, Appendix 4: Methodology [1]

These changes have the following rationale.

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1 http://www.networkrevolution.co.uk/industryzone/projectlibrary, p.52

- **General load.** The Restricted Hours and Direct Control test cells require customers to hold certain interruptible technologies – smart white goods and electric hot water heating for domestic customers, and electric heating and cooling systems for SME customers. Fewer domestic customers with smart white goods are available than envisaged at the time of the trial so British Gas and Northern Powergrid have decided to fully subsidise the cost of the smart white goods. The cost implications of this will reduce the numbers available for the trial to 150.

- **Heat pumps**. To ensure that the trial does not impact on customers' ability to heat their homes to acceptable levels, only customers with heat pumps with thermal storage will be included in the test cells where a degree of automation is applied to heating use. This will reduce the number of participants in the Direct Control and Restricted Hours test cells.

- **Electric vehicles.** To participate in the Restricted Hours and Direct Control test cells, customers must have newly purchased a British Gas charging point. This is likely to severely limit the number of customers available for the trial. Rather than spreading these across a range of test cells and reducing the scope to gain quantitative learning on any on intervention, customers with EVs and British Gas charging points will all be encouraged to participate in the Restricted Hours electric vehicle cell and subsidisation of the charging points may be considered. In addition, a pure time of use test cell will become the business as usual baseline against which other interventions are assessed. The Direct Control test cell will be omitted.

- **Solar PV.** The within premises balancing test cell will be reduced in size from 600 to 300 to reflect constraints on the learning that can be gained from this cell, due to the temporary distortions caused by the current feed-in tariff regime, and the limited availability of domestic appliances which can use more electricity at the times when PV capacity is producing output.

Tariff development

A set of tariff propositions were developed that aimed to maximise the relevant learning from the trial, given practical constraints faced in their implementation.

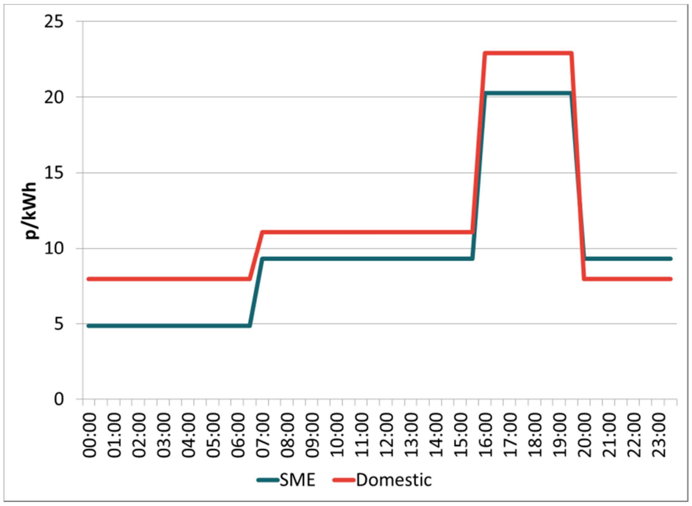
Time of Use and Restricted Hours

The Time of Use and Restricted Hours propositions are both based on an underlying time of use tariff

For a time of use tariff to be commercially viable and valuable in 2020, it should reflect the costs of supplying electricity at each point in the day in 2020, and the likelihood that shifting demand in response to tariffs will change the profile of these costs.

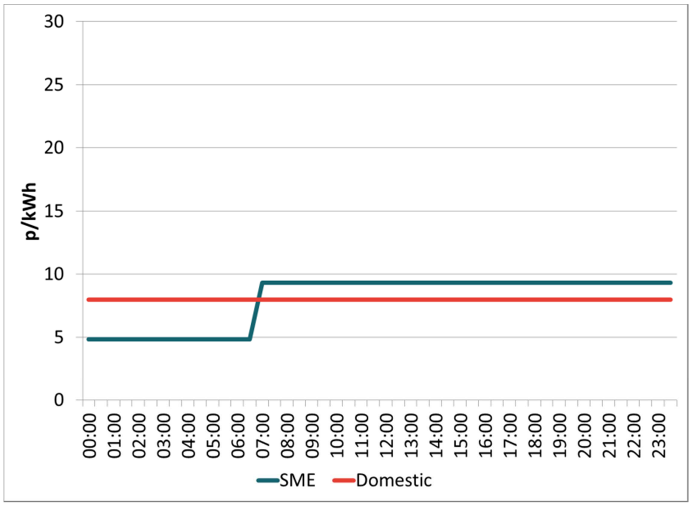
Time of use tariffs were developed for SME and domestic customers based on estimated future costs and demand patterns. These tariffs are presented in Figure 1 and Figure 2.

Figure 1. Time of Use tariffs – weekdays



Source: British Gas

Figure 2. Time of Use tariffs –weekend



Source: British Gas

The domestic and SME tariffs differ in that the domestic tariff does not include an 'evening shoulder'. Instead it reverts back to the lower night rate directly after the peak evening period. This domestic tariff will provide new learning as a tariff of this shape was not included in recent major trials in the UK and Ireland. It will allow testing of the assumption that an evening shoulder is required to avoid a new peak occurring once the lower night rate commences mid-evening. While ideally an evening shoulder would have been included for the time of use tariffs, British Gas's systems were unable to accommodate this for domestic customers.

The Restricted Hours tariff aims to test customers' behaviour with a time of use tariff combined with an automated service that switches certain appliances off during certain periods of the day, with technology provided to allow customers to easily override this automated service when they wish.

The automated service will be combined with the time of use tariff being used elsewhere in the CLNR, which will allow the incremental impact of the automation to be assessed. The default restriction will apply only over the four hour peak period from 16:00-20:00.

Direct control tariff

The aim of Direct Control tariff is to test customers' behaviour in response to the occasional direct control of the load of specific appliances, without the possibility of override. Customers will receive an annual subsidy for acceptance of these interruptions. This type of control can allow reinforcement costs at HV level to be avoided.

Northern Powergrid has developed a methodology for assessing the value associated with moving demand based on the Common Distribution Network Charging Methodology (CDCM)[2] for customers connected at low-voltage (LV) and HV network levels and its interim proposals for the (yet to be approved) EHV Distribution Charging Methodology. This analysis suggests a value of £30/kW-year can be used to estimate the value of occasional direct control of loads, assuming this intervention would be focussed on the heavily-loaded parts of the network where the value of implementing it is at the higher end. For this cost saving to be realised by networks, customers would have to allow their load to be interrupted as many times as was required to defer HV network reinforcement. Northern Powergrid estimates these interruptions would tend to last for the four hours of peak, for around 10-15 consecutive working days, once every three years.

The value to a customer of accepting a Direct Control proposition will depend on the size of load associated with the appliances that they have available for interruption. The results of our analysis of the value of interrupting domestic loads of different types are set out in Table 2. Based on these values, it was decided to exclude cold appliances from this test cell.

2 http://www.energynetworks.org/electricity/regulation/structure-of-charges-cdcm/common-distribution-charging-methodology.html

Table 2. Value of Direct Control for domestic customers

		Annual value of interrupting load at peak
Cold appliances[3]	Fridge	<£0.20/year
	Fridge-freezer	
	Freezer	
Wet appliances[4]	Washing machine	£2/year
	Dishwasher	£2/year
	Dryer	£4/year
Hot water heating[5]		£15/year
Heat pumps [6]		£10-15/year

Source: Frontier Economics

The technologies held by SME customers are much more diverse. British Gas developed a pragmatic approach to assessing the value of interrupting their loads. This is based on the assumption that interrupting the load of SME customers will allow a portion of their distribution network costs associated with supplying electricity to them to be saved. Applying this methodology results in a discount of 2% in bills to Direct Control SME customers, who can allow 20% of their load to be interrupted. A proportionately smaller discount will be given where customers can reduce a smaller amount of load.

3 Percentage of peak time that load can be interrupted for is based on the assumption of one 15 minute interruption during any 4 hour peak.

4 Usage profile based on those presented in Smart A (2008) *Synergy potential of Smart Appliances*, http://www.smart-a.org/WP2_D_2_3_Synergy_Potential_of_Smart_Appliances.pdf, scaled to be in line with Defra estimates.

5 Usage at peak based on British Gas analysis of current hot water consumption.

6 The percentage of peak time that load that can be interrupted for is based on the assumption that customers can only be interrupted for a maximum duration of 30 minutes. The thermal inertia of the insulated home and the partially charged heat store should maintain comfort during an interruption of this length.

Electric vehicle tariffs

Three test cells for electric vehicles were planned to contribute to LO2. However, rather than including a time of use tariff for electric vehicles in the LO2 test cells, a time of use tariff will be included in the Learning Outcome 1 (LO1) cells as the business as usual case against which other options will be assessed. Given the significant risk that only a small number of customers will be available, the decision was made to focus on the Restricted Hours test cell only in LO2. The automated restriction will be applied alongside the LO1 time of use tariff.

Next steps

The tariffs developed according to the methodology presented in this document will be trialled under the CLNR in the Northeast and Yorkshire distribution network regions. Learning from the trial will be fully shared and a detailed analysis of the results will be published once the trial has concluded.

1 Introduction

Northern Powergrid's Customer Led Network Revolution (CLNR) project is testing demand side response solutions across a range of customer groups. This report describes the methodology we have used to develop the domestic and small business (SME)[7] tariffs, and presents the resulting tariffs to be trialled. The methodology and the resulting tariff propositions have been developed in collaboration with Northern Powergrid and British Gas.

1.1 The CLNR

The CLNR received funding under Ofgem's Low Carbon Networks Fund in 2010.

It aims to provide knowledge and experience on the deployment of network response and demand response technologies at distribution network level. It is testing a range of customer-side innovations (innovative tariffs and load control incentives), by themselves and in combination with network-side technology (including voltage control, real time thermal rating and storage).

This report focuses on the part of the project which looks at customer-side innovations: "Learning Outcome 2" (LO2). LO2 aims to assess:

- the extent to which customers are flexible in their load and generation; and
- the cost of this flexibility.

The intention was to test customer propositions and tariffs to incentivise demand side response (DSR) on over 3,000 domestic customers and 450 small commercial customers, mainly from the area covered by Northern Powergrid's business in Yorkshire and Northeast England[8].

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7 Durham Energy Institute provided the following description of SMEs: Enterprises qualify as micro, small and medium-sized enterprises (SMEs) if they fulfil the criteria laid out below. In addition to the staff headcount ceiling, an organisation qualifies as an SME if it meets either the turnover ceiling or the balance sheet ceiling, but not necessarily both

Enterprise category	Headcount	Turnover or	Balance sheet total
medium-sized	< 250	≤ € 50 million	≤ € 43 million
small	< 50	≤ € 10 million	≤ € 10 million
micro	< 10	≤ € 2 million	≤ € 2 million

8 The trial will also include testing of responsiveness at industrial and commercial level, however that part of the trial is outside the scope of this report.

1.2 Why investigate DSR?

The move to a low-carbon economy is likely to create significant challenges for distribution networks. In particular, decarbonisation is likely to involve the following:

- electrification of heat and transport, which will increase load on distribution networks and may change the profile of demand and the proportion of demand that is flexible; and
- an increase in the penetration of distributed generation, which is likely to increase the complexity of flows on the network and may cause voltage issues.

To accommodate the roll-out of these low-carbon technologies, network reinforcement is likely to be required. DSR (involving the shifting of demand from one period to another, rather than the reduction of demand) can potentially help defer the need to reinforce networks by allowing greater use to be made of existing capacity. In this way, it has the potential to save costs at distribution network level.

1.3 Tests cells and tariff propositions

This report describes the methodology used to develop the tariff propositions for domestic and SME customers to test the potential for demand response in the CLNR trial.

The project aims to test a range of tariff propositions over a set of different customer groups. Customers are grouped according to whether they are domestic or SME customers and according to the technologies they hold. Ten 'test cells' for the trialling of tariff types on each customer group were developed to contribute to LO2[9]. The test cells included in the original bid are summarised in Table **3**.

[9] A further two learning outcome 2 test cells focus on industrial and commercial or distributed generation customers.

Table 3. Summary of test cells include in the bid

	Test cell no.	Description	Customer numbers in original bid to Ofgem
General load (white goods and immersion heaters)	9	Time of Use	600 domestic 150 SME
	10	Restricted Hours	600 domestic 150 SME
	11	Direct Control	600 domestic 150 SME
Customers with heat pumps	12	Time of Use	600 domestic
	13	Restricted Hours	150 domestic
	14	Direct Control	150 domestic
Customers with electric vehicles	15	Time of Use	50 domestic
	16	Restricted Hours	50 domestic
	17	Direct Control	50 domestic
Customers with solar PV	20	Within Premises Balancing	600 domestic

Source: Optional Appendices: Customer Led Network Revolution, Appendix 4: Methodology [10]

Three key proposition types are included in the trial.

- **Time of Use.** The Time of Use tariff is a static time of use tariff[11]. Under this tariff, customers have total discretion on how to respond to the price signals. The price signals are communicated to them through a smart meter and its associated In Home Display (IHD).

- **Restricted Hours.** The Restricted Hours tariff combines a static time of use tariff with a degree of automation**.** Certain loads (for example, immersion heaters, electric vehicles and heat pumps) are automatically reduced during the peak period as a default. However, customers are able to override the automated default reduction if they want to use their technologies during the high price periods.

10 http://www.networkrevolution.co.uk/industryzone/projectlibrary, p.52

11 Under static time of use tariff, rates vary by time of day according to a profile which is set in advance. In contrast, a dynamic time of use tariff would allow the rates to change in response to events occurring on the system in real time.

- **Direct Control.** The Direct Control tariff proposition allows certain loads to be driven from external dynamic signals. This means that these loads would occasionally be interrupted in response to certain electricity system conditions (e.g. a HV outage) occurring in real time. Customers are not able to override these interruptions.

The bid proposed to test each of these tariffs on the following customer groups:

- domestic customers without low-carbon technologies;
- SME customers without low-carbon technologies;
- domestic customers with electric vehicles; and
- domestic customers with heat pumps.

A technical solution enabling customers with solar PV panels to use the power they generate within the home (Within Premises Balancing) is also included in the trial.

This report reviews the proposed structure for each of these tariffs and proposes a set of rates for each one.

1.4 Structure of this report

The report is structured as follows:

- Section 2 sets out the principles for developing tariff propositions that meet the LO2 aims;
- Section 3 describes the role that DSR can have in reducing costs and how the type of tariff propositions included in the CLNR may contribute to this;
- Section 4 assesses the likely availability of customer groups covered by the trial; and
- Sections 5-8 describe the development of the three tariff propositions for domestic and SME customers.

2 Principles and practical issues

LO2 aims to investigate the extent to which customers are flexible in their load and generation, and what the cost of this flexibility is. In particular, it aims to:

- establish to what degree customers will accept propositions for flexibility; and
- for those customers who have accepted a proposition for flexibility, to assess the degree to which they will then respond. [12]

In this section we describe the criteria for ensuring that this learning outcome is met.

2.1 Criteria for contributing to learning outcomes

The criteria for reviewing test cells inform:[13]

- the prioritisation between test cells, in the face of practical constraints such as lack of available customers (in Section 4); and
- the development of the detailed tariff propositions (in Section 5-8).

To best contribute to the aims of LO2, our view is that each test cell included in the trial should be:

- relevant;
- provide new and robust learning; and
- be capable of being practically implemented.

We discuss each of these three criteria in turn.

2.1.1 Relevance

The test cell should focus on interventions that are likely to create value (by reducing electricity system costs) and be commercially viable in the period around 2020.

2020 has been chosen to provide a focus for these trials because, by then, significant roll out of low carbon technologies is likely to have occurred but it is still within the next electricity distribution price control period.

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12 Optional Appendices: Customer Led Network Revolution, Appendix 4: Methodology

http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=98&refer=Networks/ElecDist/lcnf/stlcnp

13 By 'test cells' we mean each combination of tariff type and customer type – see Table 1.

Learning from a test cell will be relevant if it meets the following criteria:

- It tells us about a situation which is likely to arise in 2020. That is, it focuses on:
  - network and supply conditions which are likely to prevail in 2020; and
  - technologies which are likely to be prevalent in 2020.
- It tests tariff propositions which are likely to create value, and so be commercially viable by 2020 (and which are therefore likely to be implemented by suppliers). Commercially viable tariff propositions will have the following characteristics:
  - the tariffs should reflect the costs of supplying the electricity; and
  - the benefits of the proposition should outweigh their expected implementation costs (e.g. if the proposition involves the installation of new kit, it will only be commercially viable if the cost savings across the electricity system exceed the costs of the kit).

The need to design relevant tariffs had a number of implications for the CLNR.

- To design each tariff proposition effectively, a good understanding of the likely benefits of moving demand in 2020 was required. We cover this issue in Section 3.
- To design the Time of Use and Restricted Hour propositions (which are also based on a time of use tariff), an understanding of the costs of supplying electricity by time of day in 2020 was needed. We describe our approach to estimating these costs in Section 5.
- To develop the Direct Control tariffs we estimated the value of interrupting supply to customers in 2020 . Our valuation of this is set out in Section 7.

Provision of new and robust learning

The trial should contribute to the learning by focussing on two types of question:

  - how attractive propositions are likely to be to customers, i.e. whether customers are likely to take up a given proposition; and
  - how customers behave once they have taken up a tariff.

This has important implications for the design of the tariffs. In particular, it implies that, to the extent that it is practical:

- customers should be offered a range of tariffs so that the attractiveness of different options can be gauged; and
- an attempt should also be made to ensure there is some spread of customers across a range of different tariffs, so learning on how customers behave with different tariffs can also be gained

At the same time, these potentially conflicting aims must be balanced against a requirement to ensure the results from the trial are as statistically robust as possible. This means that customers cannot be spread too thinly across test cells.

We discuss the implications of these considerations in Section 4.

The trial should also add to what has already been learnt from the results of recent major trials, including the UK Energy Demand Research Project (EDRP) and Irish Commission for Energy Regulation (CER) trials. New learning in this trial will be particularly associated with the Restricted Hours and Direct Control tariff and the inclusion in the trial of customers with low-carbon technologies. These have not been covered by previous trials. The location of this trial in the Northeast of England also differentiates it from previous trials.

Practicality

The test cells should focus on interventions that it will be possible to trial. In particular, the following will be important constraints.

- **Numbers of customers with low-carbon technologies**. The trial relies on sufficient customers being available with low carbon technologies such as electric vehicles, heat pumps and solar PV. If these customers are not available it may not be possible to investigate how customers' behaviour varies under different tariff types with these technologies. In Section 4, we discuss where prioritisation may be required.

- **System constraints.** The trial will be limited by the current information technology and systems that the project partners have in place. This may mean that some tariff propositions which are likely to be commercially viable in 2020 may not be feasible to trial at this stage. We highlight where this is the case in later sections.

The principles will inform the development of tariffs and prioritisation between test cells. We return to these principles and practical issues when describing each of the tariff proposition types in Sections 5-7.

3 The role of DSR in reducing electricity system costs

The CLNR is trialling two main tariff proposition types:

- **Static time of use tariffs.** Static time of use tariffs vary the price of electricity across the day. Static time of use tariffs will be part of the Time of Use and Restricted Hours propositions (these tariffs differ in terms of the amount of automation involved).

- **Load control tariffs**. Load control tariffs allow certain loads to be occasionally directly switched off in response to certain electricity system conditions that arise in real time. This is the key feature of the Direct Control tariff included in the CLNR.

This section sets out the rationale for focussing on these proposition types in the CLNR trial:

- first, we describe how DSR can reduce costs in different parts of the electricity sector;
- second, we explain why DSR is likely to increase in importance to 2020;
- third, we establish that static time of use tariffs are likely to help reduce electricity system costs in 2020;
- fourth we explain how Direct Control tariffs are likely to help reduce electricity system costs in 2020; and
- finally, we describe the rationale for the Within Premises Balancing tariff.

3.1 The role for DSR

This section describes the types of DSR that can reduce costs. DSR can reduce electricity system costs in a range of ways across the electricity sector.

- **Distribution networks.** Distribution network capacity must be sufficient to accommodate local peak flows to avoid thermal overload or over- or under-voltage. Reinforcement can be deferred where expected increases in peak flows can be reduced by:
  - shifting demand to off-peak times; and

  - shifting demand to the times when locally connected generation (e.g. PV) is producing output.

- **Transmission networks**. Transmission network capacity must be sufficient to accommodate system wide or regional flows. Cuts in system wide or regional peak flows mean that transmission reinforcement can be deferred.

- **Generation.** Both the quantity of generation output and the capacity that is required to generate at times of system peak drive generation costs:

  - flattening the demand profile for GB as a whole will cut the need for peak generation capacity and thereby reduce costs; and

  - shifting demand to off-peak times when more efficient plants are running, or to times when intermittent generation is producing output, can also reduce costs.

- **System balancing.** Shifting demand could also help National Grid balance the system. Because of the growing penetration of wind power, generation output will increasingly reflect unpredictable real-time changes in prevailing weather conditions. This is likely to increase the amount of short term operating reserve (STOR) that National Grid needs to procure to keep the system in balance. DSR could potentially play the same role as STOR in the balancing system.

Though DSR can reduce costs across the electricity sector, it may not be able to reduce costs in all parts of the sector at once.

- **Using DSR to reduce distribution network costs**. This may reduce transmission and generation costs, but only to the extent that local peaks coincide with system-wide and regional peaks. These peaks may sometimes coincide but are not likely to coincide where local peaks are driven by the clustering of low-carbon technologies. Where DSR is used to reduce distribution network costs, the same flexible demand will not be available for use in system balancing.

- **Using DSR to reduce transmission costs.** This type of DSR may reduce generation costs where costs are driven by system-wide rather than regional congestion. Distribution costs may also be reduced, but only where local peaks coincide with system-wide or regional peaks[14]. Again, there is likely to

[14] Strictly, in the northeast, reducing demand will increase power flows, as the transmission system is generation rich. For the purposes of this exercise, we have taken the more general assumption that reducing demand will reduce transmission flows.

be a trade-off between using the DSR to reduce transmission costs or system balancing.

- **Using DSR to move demand to the times when the marginal cost of generation is lowest.** As long as peaks in generation costs will continue to be closely related to demand peaks, this type of DSR may reduce transmission costs and distribution costs, where local and regional peaks coincide with system-wide peaks. Again, there is likely to be a trade-off between using the DSR to reduce transmission costs or system balancing.

- **Using DSR for system balancing.** Using DSR for system balancing is not likely to impact on the costs of transmission, distribution or generation.

Table 4 sets out a summary of how DSR of different types are likely to impact on different parts of the electricity sector and illustrates the likely trade-offs between using DSR for different purposes.

Table 4. Impact on costs of different demand changes

	DSR for distribution: reduce local demand peaks or match demand to local output of intermittent generation	DSR for transmission: reduce system wide demand peaks	DSR for generation: move demand to times when marginal generation costs are lowest	DSR for system balancing: ensure supply and demand are balanced at each point in time
Distribution networks costs	**Reduction**	**Potential reduction** System-wide peaks will often coincide with local peaks	**Potential reduction** Will cut costs until intermittent generation reaches high penetration levels	**Little or no impact** Will depend on the timing of system balancing needs
Transmission network costs	**Potential reduction** Only if local and system wide peaks coincide	**Reduction**	**Potential reduction** Will cut costs until intermittent generation reaches high penetration levels	**Little or no impact** Will depend on the timing of system balancing needs
Generation costs	**Potential reduction** only if local and system wide peaks coincide	**Reduction** Will cut costs until intermittent generation reaches high penetration levels	**Reduction**	**Little or no impact** No impact
System balancing costs	**Little or no impact** Will depend on the timing of system balancing needs	**Little or no impact** Will depend on the timing of system balancing needs	**Little or no impact** Will depend on the timing of system balancing needs	**Reduction**

3.2 The increasing importance of DSR to 2020

The move to a low-carbon economy is likely to create significant challenges for distribution networks. In particular, decarbonisation is likely to involve the following:

- **Electrification of transport.** The Committee on Climate Change estimate that to meet Government's statutory carbon budgets, 5% of all cars will need to be either battery electric or plug in hybrid by 2020.[15]

- **Electrification of heat.** Government is "committed to the ambition" that 12% of heating will be from renewable sources in 2020, the majority of which is likely to be from electric heat pumps.[16,17]

- **Increase in the penetration of solar PV.** Government expects around 3 GW of PV to contribute to meeting the 2020 renewables target.[18]

- **Increase in the penetration of intermittent generation.** To meet the 2020 renewable energy target, Government expects around 28 GW of wind to be on the system by 2020.[19]

Electrification of heat and transport will increase load on distribution networks, and may change the profile of demand, and the proportion of demand which may be flexible. PV will increase the complexity of flows on the network and potentially cause voltage issues. Intermittent generation will lead to more variable and unpredictable supply costs. We deal with each of these in turn.

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15 CCC (2011) *Meeting carbon budgets*, http://hmccc.s3.amazonaws.com/Progress%202011/CCC_Progress%20Report_Ch4_interactive.pdf

16 DECC (2011), *Renewable Heat Incentive* http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Energy%20mix/Renewable%20energy/policy/renewableheat/1387-renewable-heat-incentive.pdf

17 DECC (2010) *National Renewable Energy Action* Plan, http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/ored/25-nat-ren-energy-action-plan.pdf

18 DECC (2010) National Renewable Energy Action Plan: http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/ored/25-nat-ren-energy-action-plan.pdf

19 DECC (2010) National Renewable Energy Action Plan: http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/ored/25-nat-ren-energy-action-plan.pdf

Electric vehicles

Policies are currently in place to support a roll out of electric vehicles.[20] Government does not have a target for electric vehicle uptake. However, the Committee on Climate Change has assessed that to meet Government's statutory carbon budgets, 1.7 million battery-electric and plug-in hybrid cars should be on the road by 2020. This is equivalent to 5% of all cars and 16% of new cars.[21]

The load profile of each vehicle will depend on the rate at which it is charged. Figure 3 shows potential charging profiles, assuming vehicles are charged overnight. Currently it is generally expected that most chargers will be low-power and will therefore add a load of around 2 kW each while charging. This compares to a current diversified peak household load of around 1.5 kW. The addition of electric vehicles to the network could therefore greatly increase local peaks.

The more electric vehicles are clustered, the greater their local impact will be. In the next decade, due to the high purchase price compared to internal-combustion-driven vehicles, electric vehicles are likely to be purchased by those with high disposable incomes. Given current high upfront costs for electric vehicles, until the mid-2020s, clustering of electric vehicles is therefore likely in affluent neighbourhoods. This clustering may be further focussed on those communities with greater commuting distances, such as the Tyne Valley.

Electric vehicles may increase the flexibility of demand. However, because this is a very new technology with a low penetration, little is currently known about actual charging patterns and the degree of flexibility. Testing this assumption will therefore be a useful part of the CLNR project.

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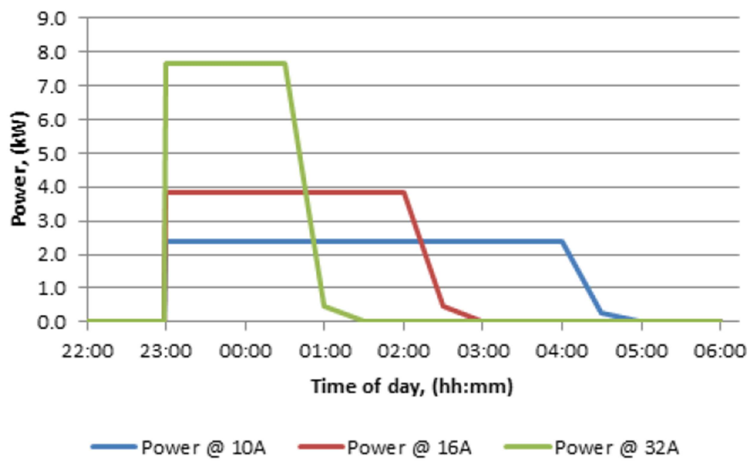
20 This includes the Plug-In Car Grant to support the purchase of electric cars, worth up to £5,000 per car. http://www.dft.gov.uk/topics/sustainable/olev/plug-in-car-grant/

21 CCC (2011) *Meeting carbon budgets*,

http://hmccc.s3.amazonaws.com/Progress%202011/CCC_Progress%20Report_Ch4_interactive.pdf

Figure 3. Charging profiles at different currents



Source: EA Technology, based on TSB (2011), *Ultra-Low Carbon Vehicles Demonstrator Programme, Initial Findings* [22]

Heat pumps

There is no Government target for the rollout of heat pumps by 2020. However, Government is "committed to the ambition" that 12% of heating will be from renewable sources in 2020[23]. Around two-thirds of this is planned to be from heat pumps[24].

As well as drawing on renewable heat in the ground and air, heat pumps demand electricity. Little is currently known about the load patterns of heat pumps although it is clear that load from heat pumps will be highest in winter[25].

22 As published in published in Frontier Economics and EA Technology (2011), An evaluation framework for smart grids http://www.ofgem.gov.uk/Networks/SGF/Documents1/RPT-STC-%20SGCBA%20final1%20-181111.pdf

23 DECC (2011), *Renewable Heat Incentive* http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Energy%20mix/Renewable%20energy/policy/renewableheat/1387-renewable-heat-incentive.pdf

24 DECC (2010) *National Renewable Energy Action* Plan,

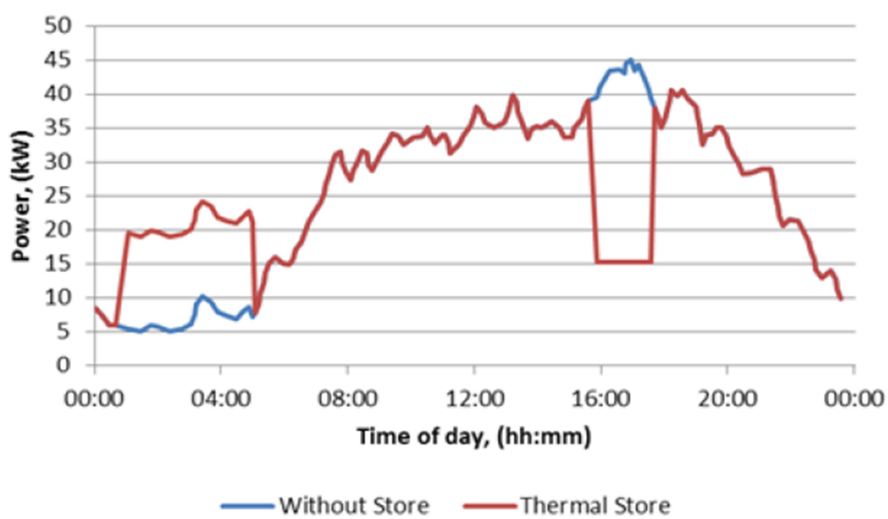
http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/ored/25-nat-ren-energy-action-plan.pdf

25 We note that if heat pumps were run backwards to provide cooling in summer, peaks in their usage could occur in both summer and winter. However, it is unlikely that domestic wet systems, such as the type included in this trial, would be used for this purpose.

Figure 4 shows five days of load data taken during some of the coldest conditions experienced during winter 2008, from an electricity substation supplying 19 properties, 18 of which had heat pumps installed. Such data suggests that peak load from heat pumps will coincide with the general network peak and that each heat pump may contribute around 2.5 kW to peak load. Heat pumps are also likely to be accompanied by auxiliary heaters, which kick in during particularly cold spells. These heaters may further add significantly to the peak. Heat pumps may therefore create new peaks in demand, particularly in local areas.

These peaks are likely to be exacerbated by clustering. Heat pumps are most attractive in off-gas-grid areas, where the main alternative fuel is oil. They are therefore likely to be biased towards rural areas. Clustering is also likely where social housing providers drive the installation of heat pumps as social housing is likely to be concentrated in certain areas.

Figure 4. Example of residential heat profile for 18 heat pumps with stylised example of storage



Source: EA Technology, based on S.D. Wilson (2010), *Monitoring and Impact of Heat Pumps, Strategic Technology Programme*[26]

Load from heat pumps is likely to be relatively inflexible unless the heat pump is accompanied by storage technology (e.g. a hot water tank), or has been installed

26 As published in published in Frontier Economics and EA Technology (2011), *An evaluation framework for smart grids* http://www.ofgem.gov.uk/Networks/SGF/Documents1/RPT-STC-%20SGCBA%20final1%20-181111.pdf

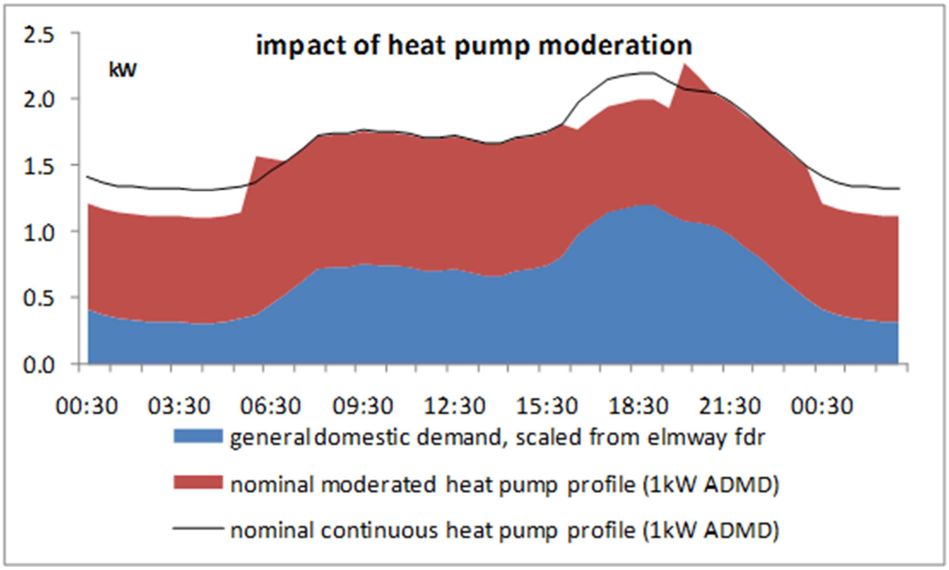
in a very well insulated home[27]. However, there may be significant "payback" when storage is employed, that is, is once the heat pump is switched back on again, its load may need to spike to higher levels to bring heat levels back to required levels in the property. This payback is not illustrated in Figure 4, which instead shows a simple stylised profile.

Figure 5 shows the alternative case. It is assumed in this figure that thermostats are adjusted down to reduce heat pump load by 20% through the peak, and that this results in a payback of 40%. Here peak demand with modified behaviour is slightly higher than that with continuous running. Under these assumptions, there would be little network benefit from modifying the behaviour of customers with heat pumps.

Given how little is known about the running of heat pumps, further investigation of the flexibility of heat pump demand, and the payback which may be associated with its use, is likely to be extremely useful.

27 Very well insulated homes (e.g. those built post-2016 under zero carbon homes regulations) are also likely to increase flexibility of heat pump demand (i.e. because home ambient temperature degradation rates are very low).

Figure 5. Potential payback for interruption of a heat pump



Source: Northern Powergrid

Solar PV

PV panels capture energy from the sun and convert it to electricity. Government expect around 3 GW of PV to contribute to meeting the 2020 renewables target.[28]

Because PV relies on the sun, its output is highest during the middle of the day and in summer time. As illustrated by Figure 6 and Figure 7, these are the times when demand is lowest. This can lead to a situation where generation could exceed local demand at some distribution substations at certain times of day. Because of this, the continued growth in the penetration of PV could place some parts of the distribution networks under pressure.

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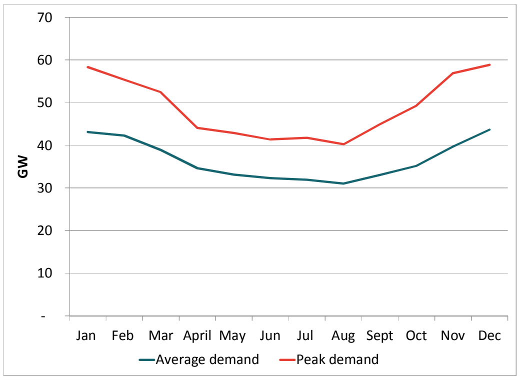
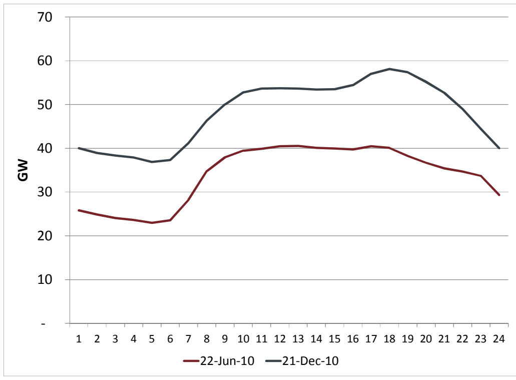
28 DECC (2010) National Renewable Energy Action Plan: http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/ored/25-nat-ren-energy-action-plan.pdf

Figure 6. Seasonal demand profile, 2010



Source: Frontier Economics, based on National Grid[29]

Figure 7. Daily profile of demand, sample weeks in 2010



Source: National Grid[30]

Large-scale intermittent generation

Decarbonisation will also increase the penetration of intermittent generation on the system. Over 28 GW of onshore wind is expected to be online by 2020 to meet the renewable target[31]. This is likely to have two impacts.

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29 INDO, http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data/

30 INDO, http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data/

- A significant proportion of wind generation will be connected to the distribution network, which may cause local network issues. However, harnessing DSR to deal with the impact of distribution–connected wind is beyond the scope of the CLNR trial.

- Wind generation will impact the predictability and variability of supply costs, as the output from wind generation will vary according to weather patterns. This could potentially reduce the role that static price signals can play.

We discuss the impact of intermittent generation on the potential role of static time of use tariffs in the next section.

3.3 The role of static time of use tariffs

Static time of use tariffs are potentially beneficial because they can reflect the shape of electricity system costs across the day, and thus encourage customers to use electricity when the costs are lowest.

This section assesses their likely continued role until 2020.

- First we describe the extent to which electricity system costs currently vary across the day.

- Then we assess the impact of increased levels of wind generation on the predictability and variability of electricity system costs, and therefore on the usefulness of static, rather than dynamic, time of use tariffs.

3.3.1 Current electricity system cost profile

Electricity system costs currently vary by time of day. Figure 8 illustrates the pattern observed in 2011. This shows that electricity costs peak in the early evening and are lowest overnight:

  - energy costs are highest when demand is highest as less efficient plants are brought on the system as demand rises;
  - transmission costs are incurred only at peak time; and
  - distribution costs are low overnight and highest at peak times.

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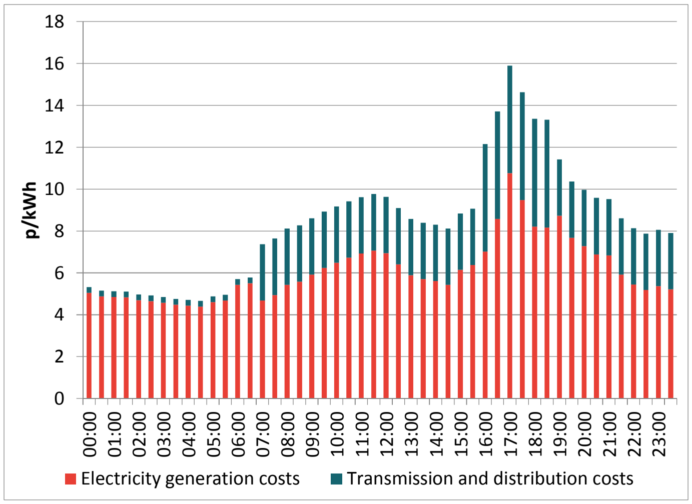
[31] DECC (2010) National Renewable Energy Action Plan, http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/ored/25-nat-ren-energy-action-plan.pdf

Figure 8. Weekday 2011 energy system costs



Source: British Gas data

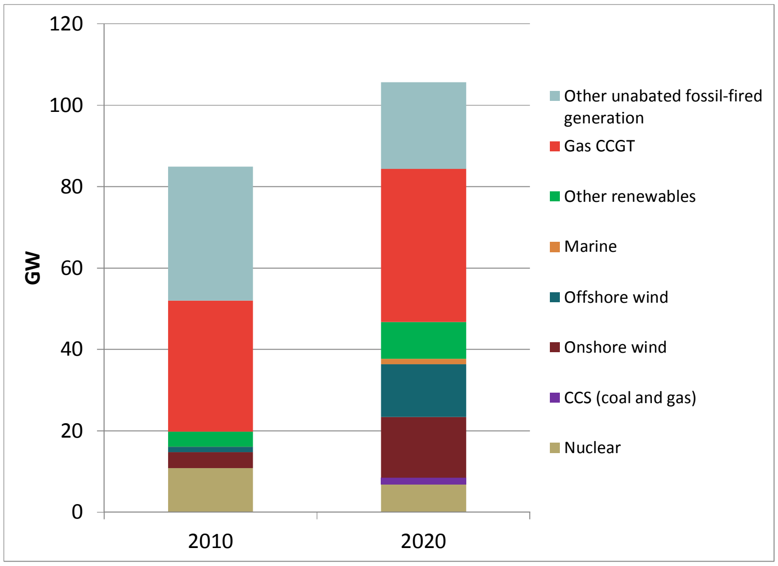
3.3.2 Impact of the increase in intermittent generation

The drive to decarbonise the economy and to meet the 2020 renewables target is likely to result in a significant change in the generation capacity mix between now and 2020. Figure 9 illustrates the expected change.

Of particular note, is the large increase expected in onshore and offshore wind capacity. The output of wind is intermittent: wind plant generates only when the wind is blowing. The large increase in wind generation could potentially result in a change in energy costs by time of day. If wind generation is a large enough part of overall generation, the costs of generation could begin to be driven by wind output, rather than by demand.

If this were the case, then a static time of use tariff, which was set in advance and was not responsive to real time wind conditions, would potentially be of limited value in 2020, and a dynamic price signal would be required.

Figure 9. Capacity mix 2010 and 2020



Source: CCC (2011) *3rd Progress Report to Parliament* [32]

We therefore decided to test the impact of the increase penetration of wind in the generation mix. The analysis set out below suggests that in 2020, wind penetration will not yet be high enough to significantly change the daily profile of costs and that static time of use tariffs will continue to provide an effective signal.

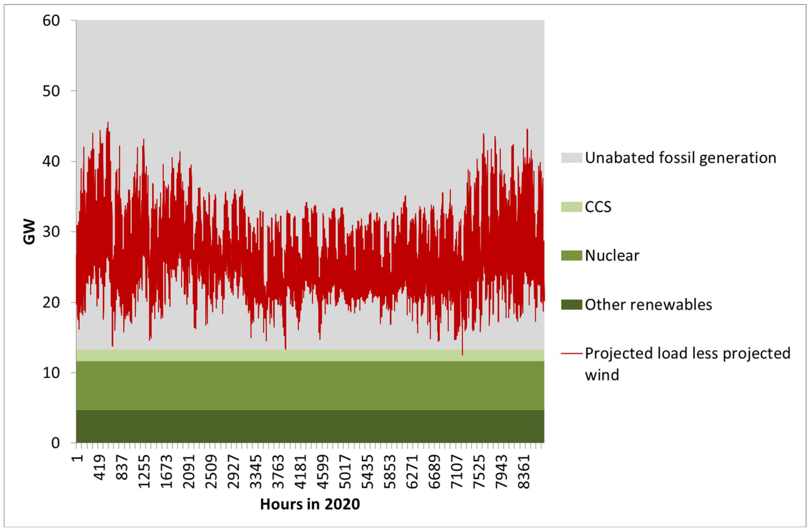
To examine the likely profile and variability of wind costs in 2020, we looked at projections of the wholesale electricity price. The wholesale price of electricity is set by the marginal plant, that is, the most expensive plant to be dispatched at each point in time. Figure 10 sets out our assessment of the likely marginal plant in 2020. The red line shows projected residual demand once wind generation has been accounted for.[33] The blocks show projected 2020 capacity, stacked roughly according to projected short run marginal cost.

The figure illustrates that even with nearly 30 GW of wind on the system in 2020, unabated fossil fuel plant remains the marginal price-setting plant for the vast majority (over 99%) of the time in 2020. This means that the presence of large quantities of wind on the system is not greatly affecting the variability of the price.

32 http://www.theccc.org.uk/reports/3rd-progress-report/supporting-data-a-research

33 This is based on the 2010 demand shape and one year's representative wind data, back-calculated from published CCC data.

Figure 10. Plant on the margin

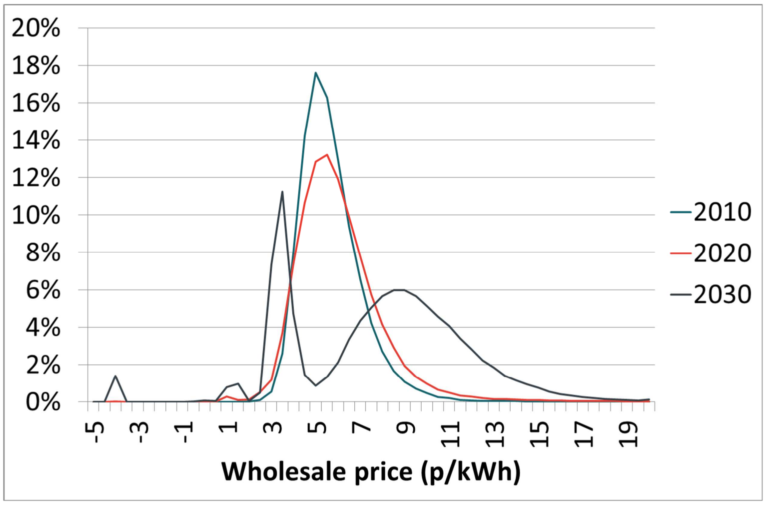


Source: Frontier Economics based on data published by the CCC

This result is consistent with published price distributions modelled for 2020. Figure 11 shows that in 2020, the price distribution curve is very similar to that in 2010, though the spread is slightly wider as higher gas and carbon prices in 2020 relative to 2010 magnify the different costs of fossil fuel plants with different efficiencies. In 2020, low-carbon plant (shown here with negative costs to reflect an assumed subsidy regime) is at the margin only 0.5% of the time. Therefore, the analysis in Figure 11 also suggests that low-carbon plant is not driving marginal generation costs by 2020.

We note that Figure 11 also shows that by 2030, assuming investment in wind continues, prices are likely to be much peakier. In this situation, with low-carbon plant driving marginal generation costs a significant proportion of the time by 2030, more complex, dynamic time of use tariffs are likely to be more effective.

Figure 11. Price distribution curves, 2010, 2020 and 2030

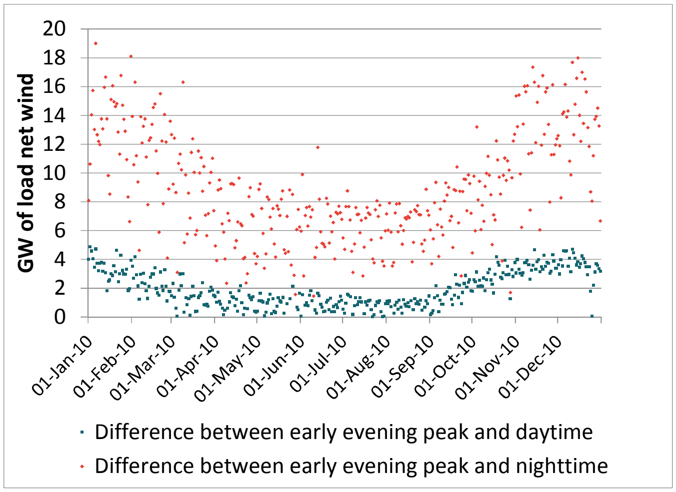


Source: Redpoint modelling for the CCC[34]

Our analysis also suggests that the peak in costs is likely to remain in the early evening peak in winter in 2020. Figure 12 shows the difference between demand net of wind (residual demand that has not been met by wind) at different times of day. The presence of wind on the system by 2020 does not change the fact that required load net of wind is likely to be at its highest in the early evening, especially in winter, and lowest overnight.

34 CCC (2009) *1st Progress Report to Parliament*, http://www.theccc.org.uk/reports/1st-progress-report

Figure 12. Demand net of wind by time of day



Source: Frontier Economics

Despite the significant change in the generation mix to 2020, the analysis presented in Figure 10 to Figure 12 therefore suggests we can assume that the profile of electricity generation cost across the day in 2020 continues to be closely related to demand, and that peaks in generation costs and demand costs will continue to coincide. This has two implications:

- static time of use tariffs will continue to deliver costs savings in 2020; and
- these static time of use tariffs can be based on a similar cost shape to todays.

We look further at the likely daily shape of electricity system costs in Section 5.

3.4 The role of direct load control propositions

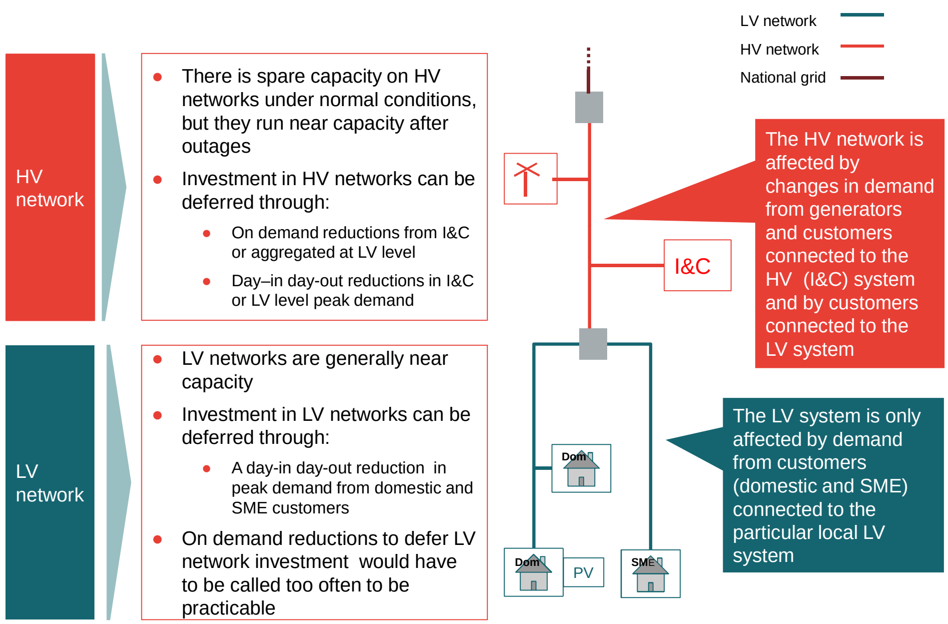
We now look at the relevance of direct load control propositions such as the Direct Control proposition to be trialled in the CLNR.

The Direct Control proposition will allow certain parts of customers' load to be interrupted in response to infrequent spikes in electricity system costs. There will be no customer override associated with this tariff type due to the importance of delivering a response with a high degree of confidence.

The type of Direct Control tariffs being looked at in the CLNR trials are designed to help reduce distribution network costs by reducing the need to reinforce the grid at HV level.

Figure 13 sets out an overview of the characteristics of the grid at LV and HV level.

Figure 13. Difference in value across different parts of the network



Source: Frontier Economics

As illustrated in Figure 13, the load on HV networks is determined by the residential and SME load that is connected at LV level, as well as by the plant and load that is directly connected to HV level. Reinforcement at HV level can therefore be deferred by managing domestic and SME demand to reduce peaks.

HV networks are built to withstand the impact of outages. The network is fully backed up so that it can keep functioning in the event of an outage. Reinforcement of the HV network can be deferred if DSR can be called at times of network outage, instead of reliance having to be put on the back-up network. Analysis from Northern Powergrid suggests that these outages would have the following frequency:

- Direct Control would need to be called from around 5% of customers in any given year;
- each day it was called, the demand response would have to last at least four hours; and

- around every three years, the response would be required for four hours on nine consecutive working days, but about 20% of outages might last significantly more than a fortnight.

Direct Control called at this level of frequency from domestic and SME customers could therefore reduce HV reinforcement costs. There will be outliers, and part of the process of CLNR is to reconcile the availability of DSR with network planning and security standards.

In contrast, LV networks are built with very little spare capacity or redundancy. When outages occur on LV networks, customers are generally disconnected. There is therefore no role for on-demand response to reduce costs at this level.

We present more details on the estimation of the value of this response in Section 7.

3.5 The role of within premises balancing

As discussed above, since PV generation relies on the sun, its output is highest during the middle of the day and in summer time.

Given the characteristics of PV load, the best demand response technique is likely to involve encouraging customers to shift demand to times when PV is generating. Static time of use tariffs or direct control measures are not likely to be effective in managing potential voltage issues caused by PV generation.

- The time of use tariff signal is not likely to help shift demand to the times when PV is generating, given the lowest price period is overnight.

- Direct control of the PV inverter would be theoretically possible. However it, it was decided not to include this measure in the trial, given it is counter-productive to the overall aim of decarbonising the economy.

Within-premises balancing, which would help customers to modify their use of energy better to match the solar generation has been included in the trial instead. This proposition is discussed further in Section 4.

3.6 Summary of the role of DSR

DSR can reduce costs across the electricity system, but there are likely to be trade-offs between the use of DSR to cut costs in different parts of the system.

The role of DSR is likely to increase to 2020 as demand response aimed at moving demand away from peak is likely to help accommodate the connection of low-carbon technologies.

Static time of use tariffs will help reduce costs by sending a cost-reflective signal to customers that provides them with a financial incentive to shift demand to when system costs are lower. While the impact of wind on the system will mean that dynamic signals may be required by 2030, our analysis suggests that static time of use tariffs will still be valuable in 2020. Direct load control propositions, allowing occasional on-demand reductions in peak demand, are likely to reduce distribution network costs at HV level. Within premises balancing may help manage issues caused by PV.

4 Populating test cells

Having established the relevance of the tariffs being trialled in the CLNR, we now look at the customer groups covered by the trial to assess the practicality of the test cells.

- We first set out the customer numbers and technology types included in the original bid.

- We then assess customer availability, given slower than expected roll out of some low carbon technologies. Where this causes divergences from the bid, we set out what is being done mitigate the impact on the learning achieved from the trial.

4.1 Customer numbers in the original bid

The original bid aimed to test tariff propositions on over 3,000 domestic customers and 450 small commercial customers.

Customers are divided in two ways across test cells in the trial:

- between SME and domestic customers; and
- by the technologies held by these customers.

The allocation in the original bid is set out in Table 5.

Table 5. Summary of test cells include in the bid

	Test cell no.	Description	Customer numbers in the original bid
General load (white goods and immersion heaters)	9	Time of Use	600 domestic, 150 SME
	10	Restricted Hours	600 domestic, 150 SME
	11	Direct Control	600 domestic, 150 SME
Customers with heat pumps	12	Time of Use	600 domestic
	13	Restricted Hours	150 domestic
	14	Direct Control	150 domestic
Customers with electric vehicles	15	Time of Use	50 domestic
	16	Restricted Hours	50 domestic
	17	Direct Control	50 domestic
Customers with solar PV	20	Within Premises Balancing	600 domestic

Source: Optional Appendices: Customer Led Network Revolution, Appendix 4: Methodology [35]

4.2 Assessment of customer availability

The requirement to include customers that already hold certain technologies, or are willing to purchase them at the outset of the trial, limits the customers available for inclusion the in the trial. The extent to which this is affects the ability to fully populate test cells in the original bid is now discussed for each type of customer.

4.2.1 General load customers (domestic and SME)

Domestic customers will fall into the general load category if they do not have a heat pump, an electric vehicle or a PV panel.[36] All SME customers fall into the general load category.

35 http://www.networkrevolution.co.uk/industryzone/projectlibrary, p.52

36 Customers with PV panels can participate in test cell 20 – Within Premises Balancing. However, they could also fall into the general load category if they wish to try the Time of Use, Restricted Hours or Direct Control propositions.

General load customers are likely to be available to populate the pure time of use tariff cell, but full test cell population may not be possible in the Direct Control and Restricted Hours cells.

- Recruitment of domestic and SME customers to the pure time of use test cells is not likely to be constrained by any factor other than the attractiveness of this tariff to customers. This is because customers are not required to hold any technology or to purchase any technology at the outset of the trial to participate.

- However, there are likely to be constraints on the recruitment of domestic customers to the Restricted Hours and Direct Control test cells. As set out in the original bid, these test cells require customers to hold either an electric hot water heater or to purchase a smart white good at the outset of the trial.

  - The aim is to recruit 600 customers with hot water heating across test cells 10 and 11. The number of customers with electric hot water heaters is currently unknown, so it is not clear how many will be available to participate.

  - 150 customers with smart white goods will be available to participate in test cells 10 and 11. The original bid included budget to partly subsidise smart appliances. However, under partial subsidisation the risk of selling too few appliances, and failing to populate the cell was high[37]. British Gas has therefore decided to fully subsidise white goods rather than attempt to sell them to participants. The subsidisation costs limit the number available for the trial to 150 customers.

- There are likely to be constraints on the recruitment of SME customers to the Restricted Hours and Direct Control test cells, as customers will require electric heating and cooling technologies to participate. The impact that this may have on customer numbers is not yet known.

These issues are summarised in Table **6**.

[37] British Gas estimates that it could sell a maximum of 28 smart white goods at the outset of the trial, based on optimistic assumptions. This assumes smart white goods would be subsided down to the price of standard white goods, recruitment from the 2000 customers in the Denwick and Rise Carr target area, a 7 year life for white goods and a conversion rate of 20%. British Gas notes that this conversion rate is highly optimistic given other sales channels available to customers.

Table 6. Generation load: customer numbers

Test cell	Description	Customer numbers in original bid	Technology required to be held by customer (not provided as part of trial)	Constraints on customer availability	Change expected over original bid
Domestic					
9	Time of Use, general load	600	None	None	**No**
10	Restricted Hours, general load	600	Prior ownership of electric hot water heater or smart white good to be purchased at the outset of trial	Penetration of electric hot water heaters is not known British Gas estimate that only 28 smart appliances would be purchased by customers so will now provide fully subsidised smart appliances	**Yes:** A reduced number of participants is expected with 75 holders of smart appliances and 300 customers with hot water heating in each test cell
11	Direct Control, general load	600			
SME					
9	Time of Use, general load	150	None	None	**No**
10	Restricted Hours, general load	150	Air conditioning or refrigeration	The number of customers with electric heating or air conditioning is not known[38]	**Yes:** The number of available participants is not yet known, and may be less than in the bid
11	Direct Control, general load	150			

Source: Frontier Economics

4.2.2 Customers with heat pumps

Roll out of heat pumps has been slower than was expected at the time that the original bid was developed. However, DECC funding may be available (and has

38 Further detail on technology choice is provided in Section 5-6.

been agreed in principle) to provide heat pumps to up to 900 customers participating in the trial. 100 of these heat pumps will have storage.

Heat pumps with storage allow demand for electricity to be shifted without impacting significantly on heat levels. A study by the Rolton Group found that heat pumps with storage could be switched down for two hours at a time without significantly impacting on comfort levels.[39]

In allocating customers between test cells, it was strongly felt that customers' ability to maintain a comfortable level of heat in their homes should not be affected. It was therefore decided that only customers with heat pumps with storage would be allocated to those test cells that entail a degree of automation (Restricted Hours and Direct Control test cells).

Table 7 summarises the changes to customer numbers over the original bid together with the rationale.

Table 7. Heat pumps: customer numbers

Test cell no.	Description	Customer numbers in original bid	Technology required to be held by customer	Constraints on customer availability	Change required over original bid
12	Time of Use, heat pump	600 domestic	Heat pump	DECC funding may provide 400 customers with heat pumps	**Yes**: 400 customers will now be included
13	Restricted Hours, heat pump	150 domestic	Heat pump with storage	DECC funding may provide100 customers with heat pumps with storage	**Yes**: 100 customers will be offered either the RH or the DC test cell, with the aim of splitting the customers evenly between test cells 13 and 14
14	Direct Control, heat pump	150 domestic			

Source: Optional Appendices: Customer Led Network Revolution, Appendix 4: Methodology [40]

4.2.3 Electric vehicles

Three test cells for electric vehicles were planned to contribute to LO2. However, the evidence suggests that customer numbers will be much more

[39] Rolton Group (2011) *Smart grid analysis report for gold standard domestic dwellings at Bedfordshire and Guildford.*

[40] http://www.networkrevolution.co.uk/industryzone/projectlibrary, p.52

limited than was thought when the bid was being put together. This is for two reasons.

- The roll out of electric vehicles has been slower than was envisaged (only 1,082 electric vehicles were registered in the UK in 2011)[41].

- The pool of customers to be included in each test cell will be further severely limited by technical requirement for customers to purchase new British Gas charging points for them to be able to participate in the Direct Control or Restricted Hours test cells.

Given the significant risk that only a small number of customers will be available, prioritisation between test cells is required. The decision was made to focus on the Restricted Hours test cell only.

- **Static time of use tariffs are likely to be business as usual for electric vehicle customers.** Since the trial was designed, all major electricity suppliers have gone to market with time of use tariffs specifically aimed at electric vehicle users.
  - Adopting a time of use tariff is likely to make sense for most electric vehicle users, given that overnight charging will tend to fit conveniently with most driving patterns, and given that the significant load associated with electric vehicles means that customers can make considerable savings by switching from a standard tariff. This suggests that time of use tariffs can be considered as the business as usual option.
  - Rather than including a time of use tariff in the LO2 test cells, a time of use tariff will therefore be included in the Learning Outcome 1 (LO1) cells as the business as usual case against which other options will be assessed. We describe this time of use tariff in Section 5.
  - Charging behaviour of electric vehicle customers against a standard tariff will no longer be considered as part of LO1.

- **Electric vehicle customers are unlikely to be charging their vehicle at the time when interruptions under the Direct Control tariff would be called.** Since the majority of electric vehicle customers are likely to be on time of use tariffs, under business as usual conditions, they are unlikely to be charging their vehicles at peak time, since these tariffs incentivise customers away from such charging. The value of them accepting interruptions in their use during peak time is therefore not likely to be high.

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41 SMMT figure provided by British Gas.

Table 8 summarises the impact of these changes on the electric vehicle test cells.

Table 8. Electric vehicle test cells: customer numbers

Test cell no.	Description	Customer numbers in original bid	Technology required to be held by customer (not provided as part of trial)	Constraints on customer availability	Change required over original bid
15	Time of Use, electric vehicle	50 domestic			Test cell will no longer be included since the LO1 tariff will now be a form of time of use
16	Restricted Hours, electric vehicle	50 domestic	Only customers with an electric vehicle and who are newly purchasing British Gas charging points	Electric vehicle roll out has been slower than expected. The requirement that only customers who are purchasing new British Gas charging points can be included is likely to further severely limit the customer uptake	May be reduced numbers Though all electric vehicle customers participating on the trial will be offered this proposition, it is not yet clear whether enough customers will be available to fully populate the cell
17	Direct Control, electric vehicle	50 domestic			Test cell will no longer be included as it is judged to be a lower priority

Source: Frontier Economics

4.2.4 Within Premises Balancing

Test cell 20 aims to trial technology which allows customers to directly use the output from their solar panels instead of exporting this power to the grid, where it may cause voltage problems at certain times. It was originally intended in the bid that customers in this test cell would be provided with a technology that allows them to use the power they are generating in a responsive load such as an immersion heater.

There is not likely to be a shortage of customers with solar PV for participating in this cell. However, the learning from this test cell will be constrained in two ways.

- There are a limited number of technologies that can be used in the test cells for within home balancing, and a limited diversity in the customer group.

- The current temporary feed-in tariff regime does not provide tariff signals that would be likely to be commercially viable in 2020.

We discuss each of these in turn.

Technology and customer types

Within Premises Balancing requires technologies which can allow customers to move some of their electricity usage to the times when output from the PV generation is high. Ideally a range of technologies and customer types would have been tested against this test cell. However, analysis by British Gas set out in Figure 14 found that only in home displays and hot water heating with storage are currently available for use in the trial.

Figure 14. Technologies for test cell 20

Potential technologies for inclusion	BG assessment of practicality	
Hot water storage	✓	Using hot water storage to balance PV generation is likely to be feasible
In-home display	✓	Providing an in-home display to provide real time information on generation patterns is likely to be feasible
Smart appliances	✗	BG's supplier of smart appliance does not offer a PV WPB option. Developing this within the timescales of the project would not be possible.
Electric vehicles	✗	There are likely to be practical difficulties in finding enough customers who have both EV and PV
Energy storage	✗	After extensive searches, BG have not found a viable domestic scale option
Smart plugs	✗	It is difficult to find appliances that smart plugs can be attached to – most white goods have cycles and cannot be stopped and started without a smart element to the appliance itself

Source: Frontier Economics based on British Gas analysis

In addition to the technology constraint, socio-demographic variation is limited by the need to include customers who have already purchased a solar PV panel. Given the high upfront costs associated with this technology, these customers will tend to be relatively affluent or based in social housing.

Lack of commercially viable tariff

Customers are compensated for power generated by solar PV under the feed-in tariff regime.[42] Under this regime, PV generation for export is currently not metered. Customers instead receive a deemed payment for export. They will receive this whether or not the generation is actually exported. There is therefore currently no cost to customers of using their own PV generation: they do not have to trade off its use against the export payment forgone.

This is an interim system only, and will be replaced by full metering of exports when smart meters are in place. This is therefore only a temporary distortion to customer signals. However, because the distortion will be present during the trial, the value of learning from this test cell is therefore reduced.

We note that Durham Energy Institute (DEI) and some experts within Northern Powergrid argued that significant learning would be possible from this test cell, despite the distortion caused by the current feed-in tariff regime. The DEI arguments are set out in Figure 15.

Figure 15. Learning from test cell 20: DEI arguments

Different contexts	Where a customer does not own the PV but is using PV in a 'rent a roof' scenario (in which a third party owns the PV and gets the export and generating income) the export income is disconnected from balancing activities, as in this cell.
Scale of the payments	The opportunity cost is small in comparison to the reduced energy bill, approximately 25% (3p (export/kWh) /12p (import from grid/kWh)), so although the situation in the test cell is imperfect from an economic point of view, the strongest of the economic signals is intact. Moreover, bearing in mind the continuously increasing domestic consumer unit price of electricity, the figure of 25% may reduce further.
The post-FiT environment	Future scenarios may not feature a FIT as it is currently structured, so learning about within premises balancing is vital, even in the knowledge that this cell does not exactly match the current FIT. Dramatic changes are likely in the long term as future regulatory frameworks move from the existing framework to one which will (a) play a full role in delivery of a sustainable energy sector; and (b) deliver value for money network services for existing and future consumers.
Other inhibitors, drivers and means of balancing	Although the economic opportunity cost of balancing is not present in this cell, energy users have other drivers and inhibitors to balancing. We are at least as interested in the effects of these and how they interact with price signals. Examples of non-economic drivers or inhibitors of balancing include habits, competencies and attitudes to organisations, the environment and communities. Furthermore we are at least as interested in how people achieve balancing as how much, so social science work in this area will be key and will be enabled by the large size of the test cell. Using only hot water to balance PV loads would limit the usefulness of this test cell in that without alternative loads to choose from, we will not be able to learn about how customers choose to make use of their micro-generated energy.
Central importance of DSM	OFGEM, DECC and others agree that dynamically managing demand through socio-technical as well as economic measures is critical to the UK's energy future as supply become intermittent and more distributed. The ways in which people's behaviour and consumption of energy might change through different interventions is central to the learning this project must deliver. This is particularly important in the context of increased real time energy price differentials as the generation features more renewables at various scales.

Source: DEI (2011) Test Cell 20: DEI Summary Perspective

42 DECC, http://www.decc.gov.uk/en/content/cms/meeting_energy/Renewable_ener/feedin_tariff/feedin_tariff.aspx

Change in test cell numbers

Based on the constraints placed on learning from this test cell due to the current feed-in tariff regime and the availability of technologies and customer types, it was agreed to reduce the number of participants in this test cell from 600 to 300 to ensure that the trials represented best value for money. This change is summarised in Table **9**.

Table 9. Within Premises Balancing: customer numbers

Test cell no.	Description	Customer numbers in original bid	Technology required to be held by customer (not provided as part of trial)	Constraints on customer availability	Change required over original bid
20	Within Premises Balancing	600	Half of customers must have a PV panel and electric hot water heating. The other half of customers can just have a PV panel.	There is not likely to be a shortage of customers with PV panels. It is not known how many customers have both electric hot water heating and a PV panel.	It was agreed to reduce the test cell in size by half given the inability to offer a commercially viable tariff in this cell, and the impact that this would have on learning.

Source: Frontier Economics

4.3 Summary

This section sets out the practical constraints associated with populating the test cells for the CLNR. The following changes will be made over the customer numbers included in the bid.

- For domestic general load customers, there will be fewer customers with smart white goods available than envisaged at the time of the trial. This affects test cells 10 and 11.

- It is not known how many domestic customers will have hot water heating and how many SME customers will have suitable electric heating and cooling systems. This may reduce the customer numbers in test cells 10 and 11.

- To ensure that the trial does not impact on customers' ability to heat their homes to acceptable levels, only customers with heat pumps with storage will be included in the test cells where a degree of automation is applied to heating use. This will reduce the number of participants in test cells 12, 13 and 14.

- There is likely to be a severe shortage of customers with electric vehicles and a suitable British Gas charging point. Rather than spreading these across a range of test cells and reducing the scope to gain quantitative learning on any on intervention, these will all be encouraged to participate in the Restricted Hours electric vehicle cell (test cell 16). The pure time of use test cell (test cell 15) will become the business as usual baseline against which other interventions are assessed and now falls into learning outcome 1. The Direct Control test cell (test cell 17) will be omitted.

- The within premises balancing test cell will be reduced in size from 600 to 300 to reflect constraints on the learning that can be gained from this cell, due to the temporary distortions provided by the current feed-in tariff regime, and the limited availability of domestic appliances which can use more electricity at the times when PV capacity is producing output.

5 Time of use tariffs

This section sets out the time of use tariff that has been developed to test on domestic and SME customers in the CLNR. The section is structured as follows:

- First, it sets out the background, describing the domestic time of use tariff test cells and their aims.
- Second, it sets out the tariff developed for use in the CLNR trial and the rationale.
- Third it describes the practical constraints associated with trialling the tariffs and presents the tariffs to be used in the trial, given these constraints.
- Finally, it sets out the time of use tariff to be trialled for electric vehicle customers.

5.1 Background

This section describes the test cells and sets out their aims.

The CLNR will include two test cells for pure time of use tariffs. As discussed in Section 4, the electric vehicle Time of Use test cell will no longer be included as part of LO2, as time of use tariffs are considered to be a business as usual option for electric vehicle customers. The two remaining Time of Use tariff test cells are set out in Table 10.

Table 10. Time of use tariff: test cells

<table>
<tr><th>Test cell number</th><th>Description</th><th>Domestic customer numbers</th><th>Commercial proposition</th></tr>
<tr><td>9</td><td>Time of Use tariff, general load (white goods and immersion heaters)</td><td>600 domestic,
150 SME</td><td rowspan="2">A pure economic signal through a time of use tariff, reflecting a distribution time of use tariff and other supply costs</td></tr>
<tr><td>12</td><td>Time of Use tariff, heat pumps</td><td>400 domestic</td></tr>
</table>

Source: Optional Appendices: Customer Led Network Revolution, Appendix 4: Methodology [43]

As set out in Section 3, the cost of supplying electricity varies significantly, but relatively predictably, across the day. This pattern is likely to persist to 2020, with cost peaks in some areas being exacerbated by the roll out of low-carbon technologies.

Static time of use tariffs can therefore potentially reduce electricity system costs by providing an incentive to customers to use electricity at the times of the day when its costs are lowest.

The learning provided by these test cells will add to what we have learnt from previous trials in the following ways.

- It includes an assessment of the behavioural response of customers with heat pumps to time of use tariffs. These customers have not been included in volume in previous trials.
- It provides a baseline for the assessment of the incremental impact of the automation being trialled in the Restricted Hours tariff.
- It tests the tariff on SMEs. SMEs were not included in the recent major UK trials (the EDRP).

43 http://www.networkrevolution.co.uk/industryzone/projectlibrary

5.2 Estimation of the cost profile for a time of use tariff

In Section 2, we set out the key principles on which tariff design should be based. We explained that the trial should test tariff propositions which are likely to be commercially viable by 2020 (and thus are likely to be actually implemented by suppliers).

For the static time of use tariffs, this means that the tariffs should reflect the costs of supplying electricity at each point in the day in 2020, and the likelihood that shifting demand in response to tariffs will change the profile of these costs. An estimation of 2020 costs by time of day is therefore required to develop time of use tariffs that could be commercially viable.

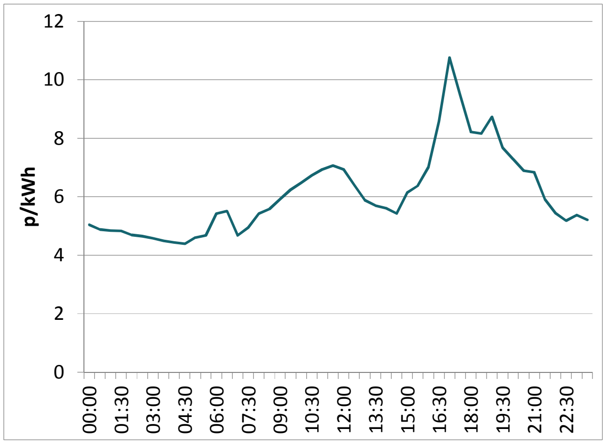
This section sets out the analysis we have undertaken with Northern Powergrid and British Gas to develop an estimated 2020 cost profile:

- we first look at the generation cost profile and likely changes to 2020; and
- we then assess likely increases in transmission and distribution costs to 2020.

5.2.1 Generation cost profile in 2020

In Section 3 we presented our analysis which suggests that the increase in wind generation to 2020 will not significantly alter the profile of marginal electricity generation costs and that the overall shape of generation costs in 2020 will remain similar to todays. We therefore based our analysis on the current shape of electricity generation costs as shown in Figure 16.

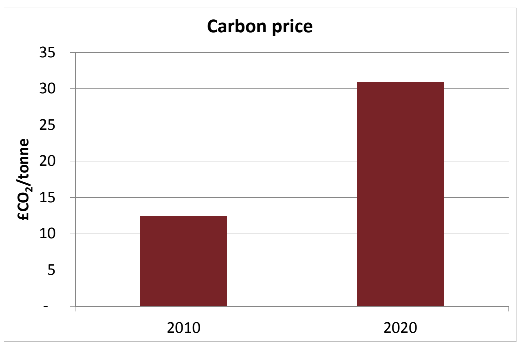
Figure 16. Current generation cost profile



Source: British Gas

Though the shape may be similar, the costs at each point in time are likely to increase, due to the increase in commodity prices projected for 2020. Figure 17 and Figure 18 show projected increases in the key commodity prices that determine the marginal costs of electricity generation.

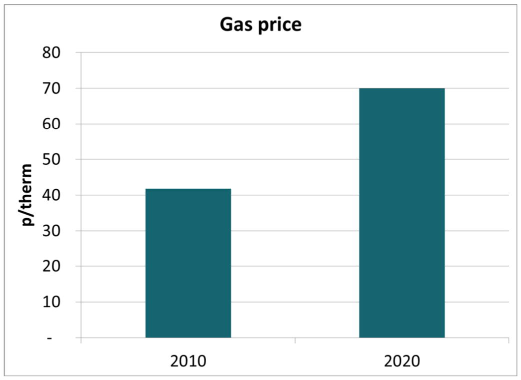
Figure 17. Current and projected 2020 carbon price



Source: Platts, HM Treasury[44]

44 All prices are in real 2010 terms.

Figure 18. Current and projected 2020 gas prices



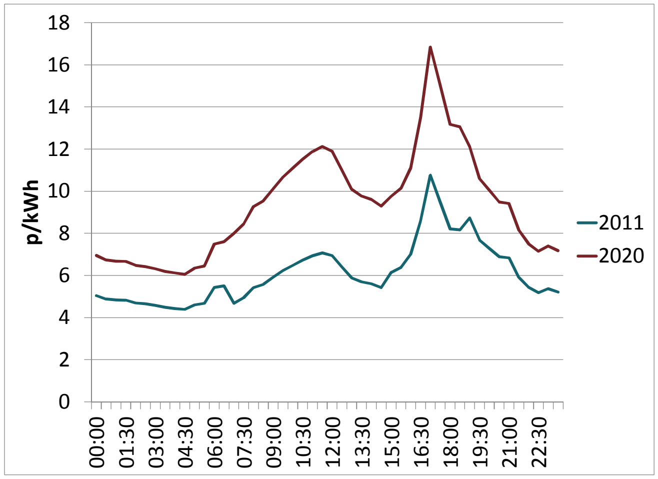
Source: National Grid, DECC[45]

The increase in electricity generation costs at peak time is due to less efficient plants coming on the system to meet higher demand. Because less efficient plants use more fuel and emit more carbon, a rise in commodity prices (principally gas prices and carbon allowance prices) will increase the differential between plant that is more and less efficient. Increasing commodity prices therefore will increase the differential between peak and off-peak electricity generation costs, as well as increasing the absolute level.

Figure 19 shows the daily generation cost profile, once the impact of rising commodity prices has been taken into account.

45 All prices are in real 2010 terms. DECC's forecast for 2020 is similar to values currently observed in ICE forward prices (once these are adjusted to real 2010 prices

Figure 19. Current and projected 2020 electricity generation cost profile



Source: British Gas

5.2.2 Transmission and distribution costs to 2020

This section sets out the expected rise in transmission and distribution costs to 2020.

Transmission costs per unit of peak demand are likely to rise to 2020. This is because of the need for major capital expenditure to accommodate the expected increase in renewable generation.[46]

To estimate 2020 transmission costs and their profile, we have made a number of assumptions.

- **Current cost reflectivity.** We assume that current transmission charges and their profile are reflective of the underlying costs.

- **Rise in costs.** We assume transmission charges will rise in proportion to the expected increase in capital expenditure to 2020. To take account of the forecast increase in transmission costs driven by the need to accommodate new intermittent generation load, we have scaled up 2011 charges in the

46 As shown in Figure 9 above, a major increase in renewable generation capacity is expected by 2020, driven by the 2020 renewables target.

Northern Powergrid (Northeast) and Northern Powergrid (Yorkshire) charging zones by around 50%[47].

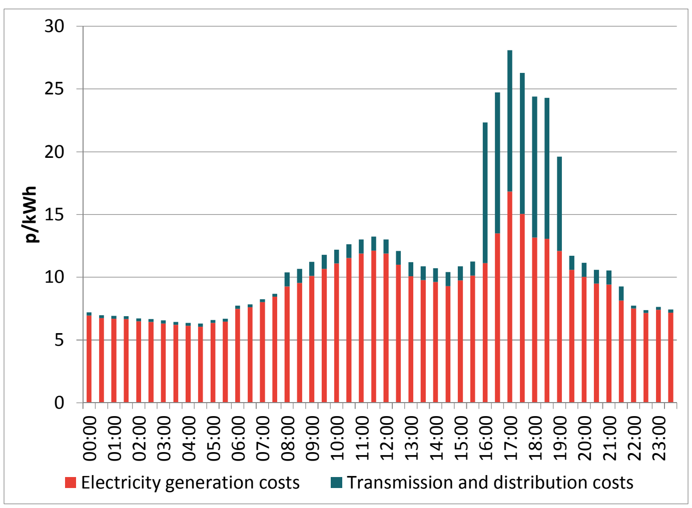
- **Profile of costs.** We assume that transmission costs continue to only be applied at peak times. In the absence of any current plans to change this structure, and assuming the structure remains cost-reflective, we have taken this to be the prudent assumption.

In contrast to transmission costs, the level of distribution costs per unit of peak demand is not expected to change significantly to 2020. We therefore use today's distribution costs per unit of energy demand and today's profile of distribution costs as the basis for our estimate of 2020 distribution costs.[48]

5.2.3 Overall projected electricity system cost profile in 2020

We then combine the projected generation, transmission and distribution cost profile for 2020. The resulting overall electricity system cost profile in 2020 for weekdays and weekends is shown in Figure 20 and Figure 21.

Figure 20. Projected cost profile in 2020, weekdays

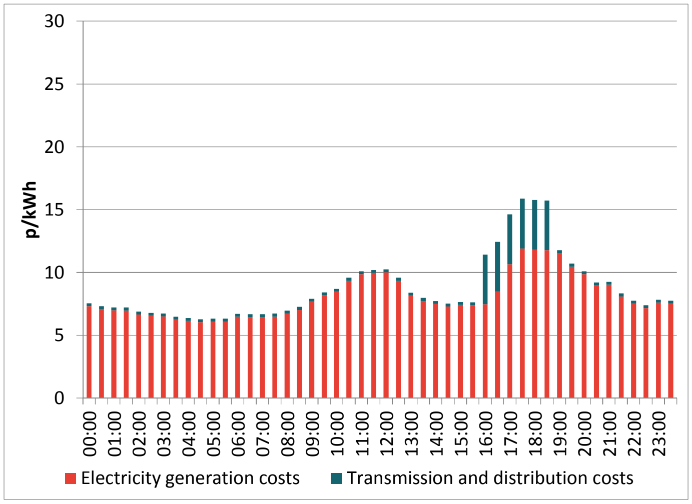


Source: British Gas

47 Assumptions based on figures in National Grid (2011) National Grid Electricity Transmission's RIIO-T1 business plan headlines, http://www.servicios-ie.telcel.com.ikaryse.appspot.com/www.talkingnetworkstx.com/business-plans.aspx

48 Specifically, we base these on uses averaged Northern Powergrid (Northeast) and Northern Powergrid (Yorkshire) 2011 HH LV (3-rate) Metered Distribution charges, http://www.northernpowergrid.com/som_download.cfm?t=media:documentmedia&i=778&p=file

Figure 21. Projected cost profile in 2020, weekends



Source: British Gas

5.3 Tariff development

We now present the tariff which was developed based on the analysis described above. We first set out the tariff initially developed. We then describe the best tariff that could be employed, given practical constraints on implementation.

5.3.1 Initial time of use tariff

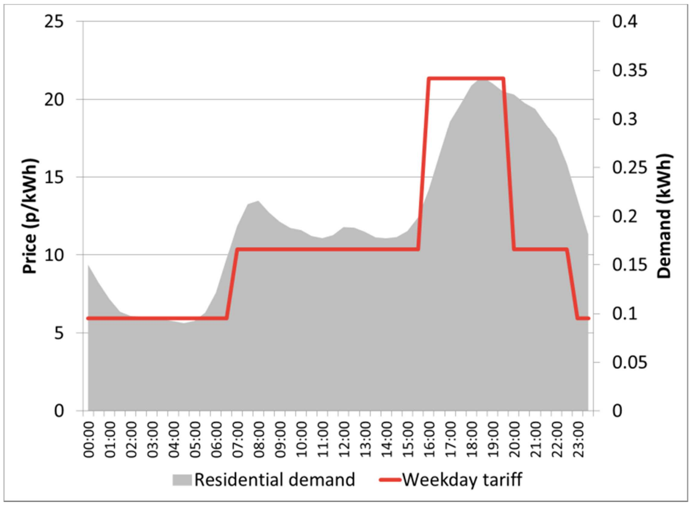
The aim of the time of use tariff is to better reflect the variation in the cost of supplying electricity across the day, and to thereby encourage customers to shift their consumption away from the times where the costs of supply are the highest. Since we are considering the potential impact of tariffs in 2020, we use differentials based on the cost profile described in Section 5.2 and set out in Figure 20 and Figure 21.

A tariff based around these absolute differentials, but adjusted downwards overall to ensure that overall the bills for the average customers remained similar, was therefore developed.

On weekdays, an 'evening shoulder' at the day rate was included from 20:00-23:00 to take account of the fact that domestic demand during the evening is still high, and that any shifting of the peak to this period would be likely to create a new domestic demand peak on distribution networks.

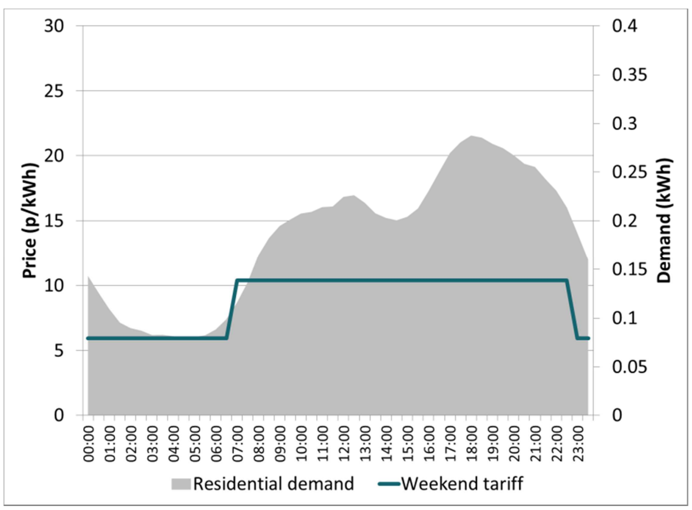
The resulting tariff is shown in Figure 22 and Figure 23.

Figure 22. Initial residential tariff, weekdays



Source: British Gas

Figure 23. Initial residential tariff, weekends



Source: British Gas

The initial tariff had the following features:

- It was based on projected 2020 costs and therefore is likely to be commercially viable in 2020.
- At weekends a day rate was applied between 7:00 and 23:00. This is to reflect higher domestic and lower industrial demand during the day at

weekends, and the potential that new low-carbon technologies such as electric vehicles could potentially create new peaks if charged at this time. This is the main area where this tariff diverged from the structure of the DUoS tariff proposed in the original bid, which applied the night (or 'green') rate all weekend.[49]

- Though the value is primarily gained from reducing costs in winter, the tariff is not seasonal. This is based on a judgement from British Gas that a seasonal tariff would greatly increase the complexity for customers and that since the learning curve for customers is already steep, it would be better to avoid additional complexity at this stage.

A set of tariffs based on this overall shape and the same differentials between time periods was also developed for SME customers. This is shown in Figure 24.

Figure 24. SME tariff

Source: British Gas

5.3.2 Practical constraints

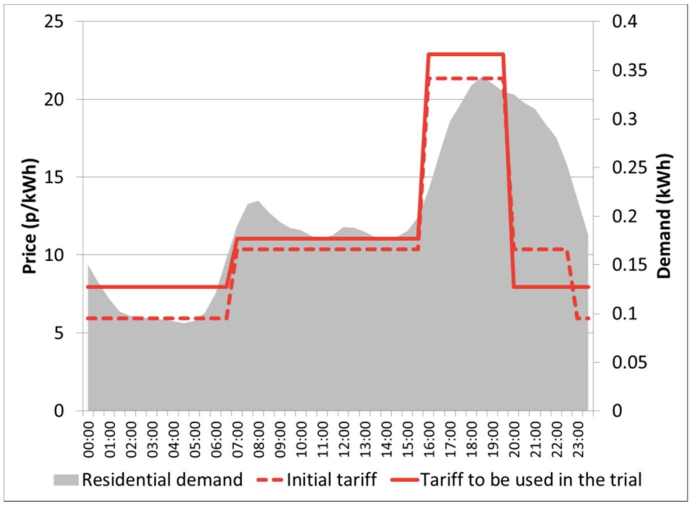
Practical constraints in British Gas's systems mean that the tariff types shown in Figure 22 and Figure 23 can only be used for SME customers.[50]

49 See Figure 28.

50 The SME tariffs contain slightly different rates from those presented in Figure 22 and Figure 23 but have the same differentials between peak and off peak charges.

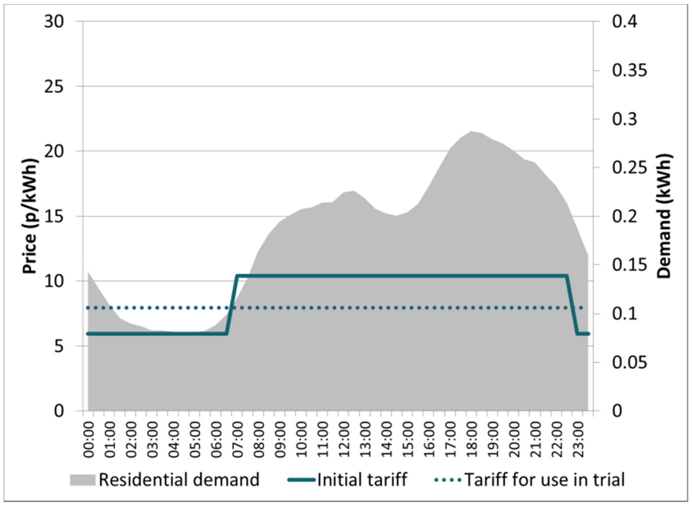
A new tariff has been developed for domestic customers. This tariff best fits the principles set out above and can be implemented using British Gas's existing systems. The new tariff is set out in in Figure 25 and Figure 26, alongside the initial domestic tariff we described above.

Figure 25. Residential time of use tariff to be used in the trial – weekdays



Source: British Gas

Figure 26. Residential time of use tariff for use in the trial –weekend



Source: British Gas

The rates in both tariffs are based on 2020 projected energy costs so are broadly reflective of electricity system wide costs on weekdays. The tariff to be used in the trial differs from the initial tariff in the following ways.

- On weekdays, the new tariff differs mainly in terms of the rate applied from 20:00-23:00. The new tariff does not include an evening shoulder and instead drops straight to the night rate after 20:00.

- At weekends, the initial tariff applies a day rate between 7:00 and 23:00, while the new tariff applies a night rate for the whole weekend. In this respect, the new tariff is in line with the structure of the half-hourly DUoS tariff, which also applies the night (or 'green') rate all weekend.

Because the tariff to be used in the trial drops sharply at 20:00 on weekdays, customers may shift demand to the evening period. Domestic demand is still high during this period, and therefore there is a risk that new domestic demand peaks are created, and that a corresponding cost is imposed on distribution networks. However, there is a large degree of uncertainty over how customers will respond to time of use tariffs of different kinds. The recent EDRP and CER trials used tariffs with an evening shoulder so there is likely to be new learning associated with trialling a tariff of this shape. In particular, the CLNR time of use tariff will allow testing of the hypothesis that an evening shoulder is required to prevent a new peak being created in the early evening. In addition, the three tier structure may make this tariff easier for customers to understand

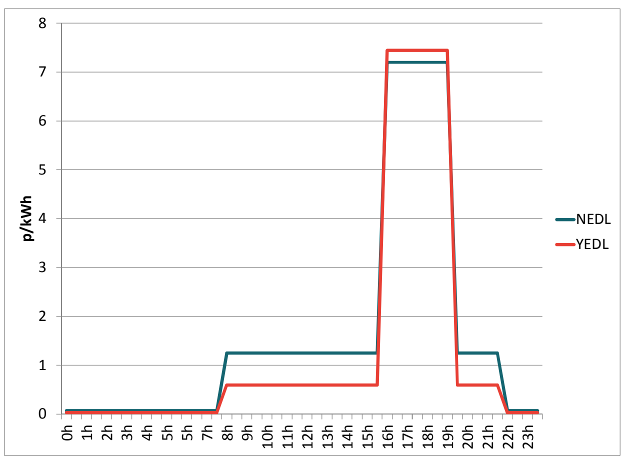
5.4 Changes to the bid

The tariff to be used in the CLNR trial is very close to that proposed in the original bid for LCNF funding. The only significant change relates to the shape of the tariff. The bid states that the intention is to develop a commercial proposition "*reflecting cost of service according to the three timebands of the current HH DUoS tariff*".

The structure of the DUoS tariff in Northern Powergrid (the Northeast) and Northern Powergrid (Yorkshire)[51] is set out in Figure 27 and Figure 28. The tariff has the following structure:

- on weekdays, a peak rate applies between 16:00-19:30;
- during the day between 8:00-16:00 and in the 'evening shoulder' between 19:30-22:00, a much lower rate applies;
- the lowest rate applies on weekday nights, and all weekend.

Figure 27. Weekday half hourly DUoS tariff – Northern Powergrid (Northeast) and Northern Powergrid (Yorkshire)



Source: Northern Powergrid (Northeast) Tariff Summary – October 2011[52], Northern Powergrid (Yorkshire) Tariff Summary – October 2011[53]

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51 Northern Powergrid (Northeast) and Northern Powergrid (Yorkshire) are the two distribution network areas in which this trial is taking place.

52 http://www.northernpowergrid.com/som_download.cfm?t=media:documentmedia&i=735&p=file

53 http://www.northernpowergrid.com/som_download.cfm?t=media:documentmedia&i=737&p=file

Figure 28. Weekend half hourly DUoS tariff - Northern Powergrid (Northeast) and Northern Powergrid (Yorkshire)

Source: Northern Powergrid (Northeast) Tariff Summary – October 2011[54], Northern Powergrid (Yorkshire) Tariff Summary – October 2011

Figure 25 -Figure 28 show that the new tariff reflects the shape of the HH DUoS tariff at weekends, but does not reflect the shape on weekdays, due to the absence of the evening shoulder.

As described above, the tariff to be used in the trial varies from the HH DUoS tariff shape on the grounds of practicality. It was not possible for British Gas systems to support a tariff which included an evening shoulder.

5.5 Time of use tariffs for electric vehicle customers

As discussed in Section 4, static time of use tariffs are likely to be business as usual for electric vehicle customers. Adopting a time of use tariff is likely to make sense for most electric vehicle users. This is because overnight charging will tend to fit conveniently with most driving patterns and the significant load associated with electric vehicle use means that customers can make noticeable savings by switching from a standard tariff. Since the trial was designed, all major electricity suppliers have gone to market with time of use tariffs specifically aimed at electric vehicle users.

Rather than including a time of use tariff in the LO2 test cells, a time of use tariff will therefore be included in the Learning Outcome 1 (LO1) cells as the business

54 http://www.northernpowergrid.com/som_download.cfm?t=media:documentmedia&i=735&p=file

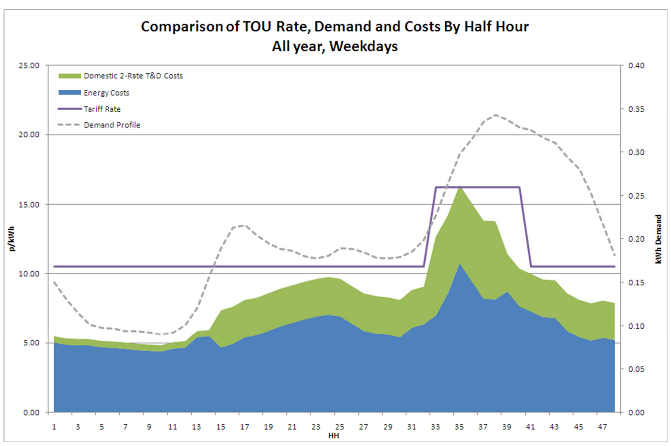
as usual case against which other options will be assessed. This tariff is based on a tariff developed by British Gas to be launched in early 2012. It will be available to all customers, whether or not they are in the trial.

The tariff has two rates, with a peak rate 36% above the standard tariff between 16:00-20:00 on both weekdays and weekends. It is compared to costs and demand profiles in Figure 29 and Figure 30.

The Restricted Hours tariff for electric vehicle customers will be based on this tariff, and will include an automated restriction over the peak period.

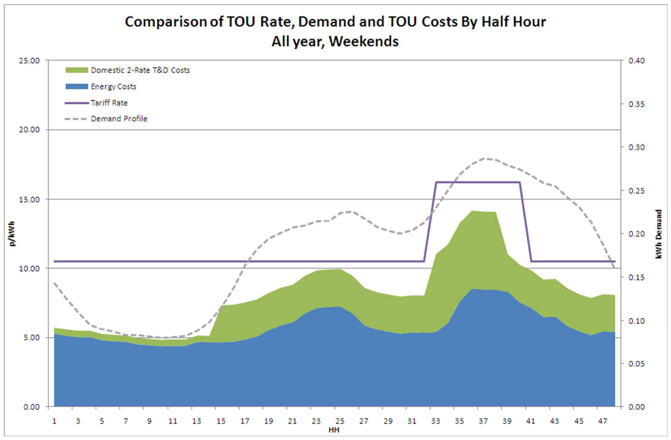
As discussed in Section 4, there are likely to be severe limits on the numbers of customers with electric vehicles available for participation in the trial. Because customers on this two-rate time of use tariff will now be monitored as part of LO1, it was decided testing customers on the three-rate tariff developed for the CLNR was not a good use of limited customer numbers. Therefore test cell 12 will no longer be included in the trial.

Figure 29. Electric vehicles - time of use tariff, weekdays



Source: British Gas

Figure 30. Electric vehicle time of us tariff, weekends



Source: British Gas

5.6 Summary

The CLNR trial will use a tariff with three rates, and three time bands in the domestic time of use cells. A two-rate time of use tariff will be trialled on electric vehicle customers as part of LO1.

An initial time of use tariff was developed by British Gas, Northern Powergrid and Frontier, which reflected the likely future costs of electricity, and included a shoulder period to reduce the risk of new peaks being created immediately after the peak period. This tariff will be used in the trial for SME customers.

Practical constraints in British Gas systems prevented the initial tariff from being implemented in the trial for domestic customers and an alternative tariff was developed which entailed the best fit to future cost profiles, given the practical constraints faced.

The new domestic tariff differs from the initial tariff, and the tariff set out in the bid, in that it does not include an 'evening shoulder'. Instead it reverts to the lower night rate directly after the peak early evening period. However, it still reflects likely 2020 energy cost profiles and trialling this tariff is expected to provide useful learning on the behaviour of domestic customers, given a tariff of this structure has not been included in recent trials in the UK.

6 Restricted Hours propositions

This section describes the development of the Restricted Hours propositions. It covers the following areas.

- First sets out the background: describing the test cells to be included in the bid and their aims.
- It then summarises changes to this tariff proposition compared to what was included in the bid and sets out the rationale for these changes.

6.1 Background

The three test cells covering the Restricted Hours propositions are shown in Table 10. These cover both SMEs and domestic customers, and include domestic customers with smart appliances, immersion hot water heaters, electric vehicles and heat pumps with storage, and SME customers with electric heating and cooling systems.

Table 11. Restricted Hours test cells

Test cell	Description	Customer numbers	Commercial proposition included in the bid
10	Restricted Hours, general load	375 domestic 150 SME	A combined commercial proposition reflecting cost of service according to a restricted hours tariff akin to Economy 7
13	Restricted Hours, heat pump	c. 50 domestic customers (100 customers to be spread between Direct Control and Restricted Hours cells)	A combined commercial proposition reflecting cost of service according to an economy 20 tariff, i.e. a tariff that precludes the use of key loads in the evening peak)
1316	Restricted Hours, electric vehicle	50	A combined commercial proposition reflecting cost of service according to a restricted hours tariff akin to Economy 7

Source: Frontier Economics

The Restricted Hours propositions aims to test customers' behaviour with a time of use tariff combined with an automated service that switches certain appliances off during certain periods of the day. Customers will have ability to easily override the automation via a switch.

The automation is not accompanied by any additional financial signal over and above that already provided by the Time of Use tariff. The automation should help rather than inconvenience the customer as it facilitates an automatic response to the price signal, but also allows them to override the signal and use their appliances during peak times when they wish.

New learning will be provided by this tariff proposition in a number of ways.

- Automated time of use tariffs were not tested in the recent EDRP and CER trials. Trialling this tariff will therefore provide new learning. In particular, the combination of this tariff with the pure time of use tariff will allow the incremental impact of the automation to be assessed.

- This tariff will be tested on customers with electric vehicles and on customers with heat pumps (though, as described in Section 5, the restriction will be accompanied by the two-rate tariff for electric vehicles). Little is known about the behavioural response of customers with these kinds of technologies.

6.2 Changes to the bid

There are two main changes compared with the original bid.

- There has been a change in the tariff underlying the restriction.

- The set of technologies to be included in the test cells has also been altered.

We now describe each of these in turn.

6.2.1 Choice of tariff to accompany automation

The original bid proposed to offer domestic and SME customers the chance to automate the response of certain loads in their households or businesses to signals. A tariff akin to Economy 7 for general load and electric vehicles and akin to Economy 20 for heat pumps was to be applied.

Economy 7 is a two-rate time of use tariff and has the following features:

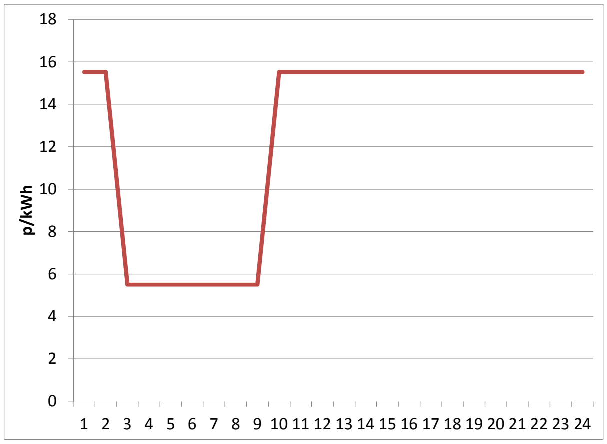
  - Electricity is supplied at a lower rate for a total of 7 hours between 10pm and 8am, with the actual times of supply set by the supplier.

  - At all other times, including weekends during the day, electricity is supplied at a higher rate.

Economy 20 is not a tariff that is available in the GB market, although it has been a standard offering on Jersey and in other jurisdictions for some years, but the bid describes it as a tariff '*that precludes use of key loads during the early evening peak*'.[55]

An example of an Economy 7 tariff is shown in Figure 31.

Figure 31. Example of Economy 7 tariff – weekdays and weekends



Source: Rates are based on those published in http://www2.savetodaysavetomorrow.com/documents/R77_02_09_v12_eco.pdf , Yorkshire region. The timings are illustrative only.

However, when developing the overall proposition it was decided to apply the same three rate time of use tariff as was used in the pure time of use cells for general load and heat pump customers. For electric vehicle customers, the two rate tariff described in Section 5 will be applied. There are two reasons for this.

- First, this allows assessment of the incremental impact of the automation over and above the time of use tariff alone. If the Restricted Hours tariff was trialled with the Economy 7 and Economy 20 type tariffs as proposed in the original bid, it would not be possible to gain this learning.

- Second, a three rate time of use tariff, such as that described in Section 5, is likely to be more cost-reflective than a two rate Economy 7 type tariff and is therefore more likely to be commercially viable in 2020.

The restricted period will follow the shape of the tariff and customers' usage will be restricted as a default over the four hour early evening period on weekdays for SME and domestic customers.

[55] An example of an Economy 20 tariff is available here: www.jec.co.uk/userfiles/files/Domestic%20Tariff.pdf

6.2.2 Technology choice

The rationale for the choice of technologies for each test cells is now set out. Changes have been made to the general load and heat pump test cells.

General load

The original bid set out that the Restricted Hours general load test cell would cover:

- white goods and hot water heating for domestic customers; and
- electric cooling systems and refrigeration for SMEs.

It has been decided to narrow the scope of technologies to be included in these cells to ensure robust learning can be gained.

- **Domestic customers**. As set out in Section 4, it has been decided to fully subsidise the smart white goods for use in this test cell, on the grounds that not enough customers would be likely to purchase the required smart goods at the outset of the trial to adequately populate the test cells. This means that a reduced number of customers with smart goods will be included in the test cell.[56] To avoid spreading customers thinly across a range of white goods, one white good, a washing machine was chosen.

- **SMEs.** It was decided to focus on electric heating and cooling systems rather than refrigeration in the SME test cell. This is because there are likely to be few SME customers with smart refrigeration systems available to join the trial. The results of customer surveys being carried out under LO1 will inform the technologies that are targeted in the Restricted Hours and Direct Control test cells.

Heat pumps

In allocating customers between test cells, it was strongly felt that customers' ability to maintain a comfortable level of heat in their homes should not be affected.

It was therefore decided that only customers with heat pumps with storage would be allocated to those test cells that entail a degree of automation (Restricted Hours and Direct Control test cells).

56 Analysis by British Gas suggests that if customers were expected to buy smart appliances to participate, the most optimistic scenario would result in 28 customers making these purchases, given the rate of turnover in white goods and the fact that these tend to be a distress sales. The decision was therefore made to fully subsidise 75 white goods for inclusion in this test cells.

Research by the Rolton Group suggests that with some pre-charging of heat pump storage, the heat pump energy use can be reduced by up to 20% (depending on property type) during the four hour peak period without significantly impacting on comfort levels. A possible approach to operating heat pumps in the restricted hours test cell is suggested below:

- since the peak period lasts for four hours, customers in this test cell will be split into two groups;
- customers in both groups will pre-charge their heat stores from 15:00-16:00;
- for the first customer group, heat pumps will be turned down from 16:00-18:00, then released to normal operation; and
- for the second customer group, normal heat pump run rate will be maintained from 16:00-17:00 but heat pumps will be turned down from 17:00-19:00, then released to normal operation.

This has the potential to produce a reduction in demand across three hours of the four hour peak. This incomplete coverage, coupled with the inevitable payback, makes it likely that little benefit will in practice be gained from this approach. However, more severe regimes seem impractical, and testing something is preferable to ignoring the issue.

6.3 Summary

The Restricted Hours tariff aims to test customers' behaviour with a time of use tariff combined with an automated service that switches certain appliances off during certain periods of the day, with technology provided to allow customers to easily override this automated service when they wish.

A number of changes have been made to this proposition over the original bid.

- The automated service will be combined with the tariff being used in the Time of Use test cells, rather than with an Economy 7 type tariff. This will allow the incremental impact of the restriction to be assessed.
- The general load cells will focus on a smaller set of technologies than included in the bid: washing machines for domestic customers and electric heating and cooling for SME customers.
- To avoid the risk of impacting on customers' ability to heat their homes, only heat pump customers who have storage will be included in this test cell and their heat usage will only be restricted for two hours out of the four hour peak period.

7 Direct Control propositions

This section sets out the development of the Direct Control propositions:

- first, we set out the background, describing the aims of the test cell and the test cells include in the original bid;
- second, we set out our methodology for estimating the reduction in electricity system costs that could be delivered by Direct Control propositions; and
- third we summarise changes to the proposal originally included in the bid.

7.1 Background

Table 12 sets out the Direct Control test cells. As discussed in Section 4, a test cells for electric vehicles will no longer be included in the trial due the severe constraints on the number of customers likely to have an electric vehicle along with the required charging point.

Table 12. Direct Control test cells

Description	Customer numbers	Commercial proposition
Direct Control, general load	600 domestic, 150 SME	An additional discount reflecting the benefit to supplier/TWO and distributor of a further level of externally controlled response is provided
Direct Control, heat pumps	50 domestic	

Source: Optional Appendices: Customer Led Network Revolution, Appendix 4: Methodology [57]

The Direct Control test cells aim to test customers' behaviour in response to a proposition whereby the load of specific appliances can be directly controlled, without the possibility of override. Customers will receive an annual payment to compensate them for allowing some of their appliances to be controlled in this way.

57 http://www.networkrevolution.co.uk/industryzone/projectlibrary

As discussed in Section 3, on-demand response can help avoid reinforcement costs at HV level. Distribution networks are likely to call this response at times of HV network outage, which will tend to occur relatively infrequently. The proposition therefore needs to be such that:

- Direct Control would need to be called from around 5% of customers in any given year;
- each day it was called, the demand response would have to last at least four hours; and
- around every three years, the response would be required for four hours on nine consecutive working days, but about 20% of outages might last significantly more than a fortnight.

7.2 Estimating the cost savings from Direct Control

This section is structured as follows.

- First we estimate the value of DSR at times of HV network outage. For the proposition to be commercially viable, a subsidy in line with this level would be required in 2020.
- We then estimate the value of occasional on-demand response elsewhere in the electricity sector.
- Finally, we summarise the implications for tariff propositions.

7.2.1 Estimating the value of customer response to distribution networks

Northern Powergrid has developed a methodology for assessing the value associated with moving demand. We first present the calculation of average value of DSR at HV level. We then look at a more bespoke approach to assessing the value at EHV level.

Calculation of average value at HV level

Northern Powergrid's methodology is based on the Common Distribution Network Charging Methodology (CDCM).[58]

The CDCM spreadsheet can be used to calculate the reduction in network charge associated with a reduction in the domestic peak of 3 hours during each of the

[58] The CDCM has been adopted by GB electricity distributors. http://www.energynetworks.org/electricity/regulation/structure-of-charges-cdcm/common-distribution-charging-methodology.html

winter peak days. This can then the converted to a value per kW reduction in peak demand per year.

The following assumptions are implicit in this methodology.

- Counterfactual network investment proceeds so that 2020 network headroom is similar to today's on average.
- Current network charges are a good representation of the marginal cost of reinforcement in 2020.

Northern Powergrid's methodology is set out in in Box 2. The resulting estimates are presented in Table 13.

Box 2: Northern Powergrid's estimation of the value of DSR to networks using CDCM

Analysis based on the CDCM allows an estimate for the value of DSR to be produced.

- **Load factor** describes how flat the load curve is for that group**.** It is calculated as average consumption over maximum consumption in the peak half-hour period.
- **Coincidence factor** describes how that group contributes to general network demand. Coincidence factor is calculated as the demand in that group at time of general network peak over peak demand for that group.

Flexing the load factor and the coincidence factor for customers in in the Northern Powergrid (Northeast) CDCM model for 2011/12 charges allows a value for DSR to be derived:

Category	**Algorithm**	Residential UR	Residential UR - 10% reduction in CF	Residential UR - 10% increase in LF
Average consumption (MWh)	**A** (from table 1053 in inputs page of CDCM model)	3.667	3.667	3.667
average demand (kW)	**B** = A * 1000 / 8760 (hrs/yr)	0.418	0.418	0.418
load factor	**C** (from table 1041 in inputs page of CDCM model)	0.415	0.415	0.456

coincidence factor	**D** (from table 1041 in inputs page of CDCM model)	0.844	0.760	0.844
maximum demand for class (kW)	**E** = B / C	1.01	1.01	0.92
kW @ system peak	F = E * D	0.85	0.77	0.77
Average charge (£)	**G** (Table 3802 in summary page of CDCM model)	86.367	82.223	82.553
£/kW (reduction in contribution to system peak)	**H** = ΔG / ΔF		48.679	49.281

As around half the gross asset value of the network lies in its LV cables, we can assume that the £50/kW/year benefit for DSR is split evenly between higher and lower voltage tiers.

The same analysis for Northern Powergrid (Yorkshire) gives a figure of £40/kW/year.

Table 13. Estimates of average DSR[59]

	LV level	HV level (including EHV)	Total
Annual value per kW reduction	£22.5/kW/year	£22.5/kW/year	£45/kW/year

Source: Northern Powergrid analysis

Bespoke valuation at EHV level

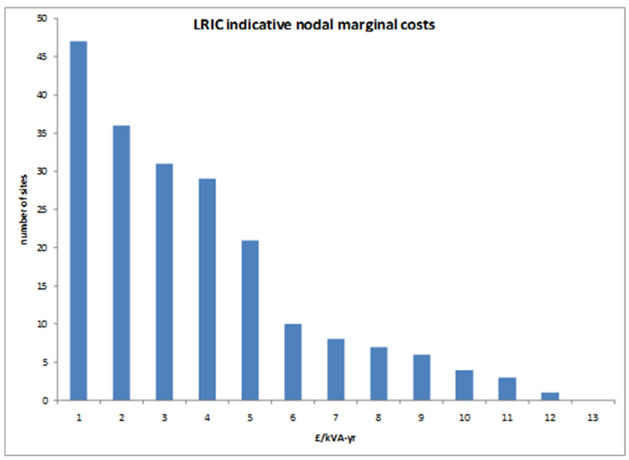
There is a large degree of diversity in the value of demand response across the EHV network. There are also much fewer nodes than at other voltage levels, Bespoke pricing (for each zone, rather than for individual customers) therefore is desirable and practical at these levels, for example through the aggregation of

59 We have sense checked these values against a figure of £30/kW/year or (£250/kW) for HV network reinforcement previously estimated for the ENA, http://2010.energynetworks.org/storage/DOC%20-%20ENA%20final%20report%20-%2001-04-11%20-%20STC.pdf

domestic or SME response. It is therefore useful to look at the distribution of value within a network, rather than just considering the averages.

Figure 32 sets out a distribution of the value of reducing peaks across EHV network in Northern Powergrid (Northeast) and Northern Powergrid (Yorkshire). This is based on values being collated by GB distributors as part of the development of a common EHV distribution charging methodology. Unscaled marginal costs from the long-run incremental costs (LRIC) model proposed for the EHV distribution charging methodology, as provided to Ofgem in April 2011, show a range from zero to £12/kW/year, with a mean of £3/kW/year. Lower values are attached to those sites with the most headroom.

Figure 32. LRIC illustrative nodal marginal costs[60]



Source: Northern Powergrid

The values shown in Figure 32 can be combined with the values of demand response for HV networks set out in Table 13 as follows.

- The generic £22.5/kW/year value for demand response found using the CDCM model includes an average of £3/kW/year of EHV.
- However the value of EHV can range from £0 to £12/kW/year delivered.

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60 It should be noted that this approach is still under development and subject to Ofgem approval.

- The total value of a kW of demand response delivered in a given HV location could therefore vary between £22.5 and £34.5/kW/year of demand response delivered.

In the development of Direct Control charges below, a value of **£30/kW/year** is used on the basis that this type of proposition would be focussed on the parts of the network where the value of implementing is at the higher end.

Estimating the value of response across the rest of the electricity sector

To check that it makes sense to control the load of domestic customers to reduce distribution network costs rather than costs elsewhere in the electricity sector, we have estimated the value of occasional on-demand response across the rest of the electricity sector.

We assume that the on-demand response can play a similar role to investment in Open Cycle Gas Turbine (OCGT) in accommodating peak load in the generation sector, managing congestion on the transmission network and reducing investment in standing reserve in the balancing market.

We estimate the investment in OCGT as having a value of £42/kW/year, based on the annualised investment cost of an OCGT.[61] This is an upper limit on the value of DSR to other parts of the electricity sector. Importantly, this figure cannot be added to the distribution network savings, as the generation and transmission network peaks are unlikely to coincide with times of HV network outage.

Though the upper limit on the value to the rest of the electricity sector may be higher than the value to the distribution network, given the uncertainty around each of these estimates, and the focus of the CLNR on distribution networks, we conclude that a tariff proposition which focuses on reducing costs to distribution networks rather than costs to the rest of the electricity sector could certainly be useful in 2020, and is worth trialling.

7.2.3 The value of Direct Control by technology – domestic customers

The value to a customer of accepting a Direct Control proposition will depend on the size of load associated with the appliances that they have available for interruption. We undertook some analysis looking at the value of interrupting

61 The cost of OCGT is based on a capital cost of £359/kW annualised over 20 years at 10% real discount rate. The source of the capital cost is Mott Macdonald (2010) *UK Electricity Generation Costs Update*, http://www.decc.gov.uk/assets/decc/statistics/projections/71-uk-electricity-generation-costs-update-.pdf. This compares to values of investment avoided of £58 -£94/kW/yr found in Ofgem (2010) *Demand Side Response.*

loads of different types. Table 14 sets out the average load when operating of the key appliances and technologies to be included.

Table 14. Average load when operating of household appliances

		Average load when operating (W)
Cold appliances	Fridge	20
	Fridge-freezer	43
	Freezer	33
Wet appliances	Washing machine	995
	Dishwasher	1453
	Dryer	2588
Hot water heating		500
Heat pumps		2770[62]

Source: Defra [63]**,** National Grid[64],

These figures need to be adjusted in two ways before the value of interrupting the load can be calculated.

- Interrupting the load only creates a value if the appliance is operating at peak. Cold appliances which are always switched on can be assumed to operate at their average load throughout the peak period. However, the average load of the other appliances needs to be adjusted to take account of the fact that they will not always be operating at peak times.
- Some appliances cannot be interrupted for the whole peak period.

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62 Rolton Group (2011) *Smart grid analysis report for gold standard domestic dwellings at Bedfordshire and Guildford.*

63 Defra (2008) *Act on CO2: Data, methodology and assumptions*, http://www.puretrust.org.uk/filelibrary/actonco2_calc_methodology.pdf

64 National Grid (2011) *Operating the Electricity Transmission Networks in 2020*, http://www.nationalgrid.com/NR/rdonlyres/DF928C19-9210-4629-AB78-BBA7AD8B89D/47178/Operatingin2020_finalversion0806_final.pdf

- It is assumed that cold appliances can only be interrupted for one 15 minute period within any 4 hour period without impacting on performance.
- Rolton Group analysis suggests that heat pumps could be interrupted for 30 minutes with no prior notice during the 4 hour period without significantly impacting on customers' comfort levels.

These adjustments, and the resulting value of Direct Control by technology type, are set out in Table 15.

Table 15. Average load when operating of household appliances

		Average load at peak	Percentage of peak time that load can be interrupted for	Annual value of interrupting load at peak
Cold appliances[65]	Fridge	20	6%	<£0.20/year
	Fridge-freezer	43	6%	
	Freezer	33	6%	
Wet appliances[66]	Washing machine	53	100%	£2/year
	Dishwasher	82	100%	£2/year
	Dryer	126	100%	£4/year
Hot water heating[67]		500	100%	£15/year
Heat pumps[68]		2770	13%	£10-£15/year[69]

Source: Frontier Economics

One of the principles for developing tariff propositions identified in Section 2 is that the benefits of the proposition should outweigh the expected implementation costs of the tariff (e.g. if the proposition involves the installation of new kit, it will only be commercially viable if the cost savings across the

65 Percentage of peak time that load can be interrupted for is based on the assumption of one 15 minute interruption during any 4 hour peak.

66 Usage profile based on those presented in Smart A (2008) *Synergy potential of Smart Appliances*, http://www.smart-a.org/WP2_D_2_3_Synergy_Potential_of_Smart_Appliances.pdf, scaled to be in line with Defra estimates.

67 Usage at peak based on British Gas analysis of current hot water consumption.

68 The percentage of peak time that load that can be interrupted for is based on the assumption that customers can only be interrupted for a maximum duration of 30 minutes. The thermal inertia of the insulated home and the partially charged heat store should maintain comfort during an interruption of this length.

69 From the Rolton work on heat pumps with a thermal store it was calculated that in the order of 0.4 to 0.5 kW peak load reduction could be achieved. This equates to £12 to £15 per year benefit. A calculation based on a 13% load reduction during peak times produces a value of £10 per year.

electricity system exceed the costs of the kit). Based on the estimates for the value of directly controlling cold appliance load set out in Table 15, it was therefore decided to exclude cold appliances from this test cell.

7.2.4 The value of Direct Control for SME customers

Estimating the value of Direct Control for SME customers was more challenging, given the greater appliance diversity of these customers.

British Gas developed a pragmatic approach to assessing this value. This is based on the assumption that the value of the interruption to the network is directly proportional to the distribution costs related to the HV network charged at the site.

Since the interruptions to customers' load will only be called at times of HV outage, only HV distribution costs will be reduced by this intervention.

- HV network outages will not always coincide with the highest transmission network peaks. Therefore this proposition cannot be assumed to save transmission costs.

- As set out in Section 3, LV networks are built with very little spare capacity or redundancy. When outages occur on LV networks, customers are generally disconnected. There is therefore no role for Direct Control response to reduce costs at this level.

Applying this methodology results in a discount of 2% in bills to Direct Control SME customers, who can allow 20% of their peak load to be interrupted at times of HV network outage. A proportionately smaller discount will be given where customers can reduce a smaller amount of load.

7.2.5 Proposition

The value of interrupting customers will only be realised for networks if they can interrupt customers' load as many times as is required to defer investment in HV network reinforcement.

Northern Powergrid analysis suggests that for 90% of situations 10-15 interruptions on consecutive working days could be expected around once every three years.

In some years, the number of interruptions would need to be greater than 10-15, for example in the event of disruptive failure at a major transformer. This could be dealt with in a tariff proposition by offering customers an additional payment for every interruption they were required to accept over the number of interruptions included in their contracts.

However, it was decided for the purposes of this trial, that including a provision for additional interruptions in the contracts would add too much complexity, and that it would be better as a first step to test whether customers were likely to accept 10-15 interruptions on consecutive working days, with a maximum figure included in the contract.

7.3 Changes to the bid

There are two main changes compared with the original bid.

- The tariff to be combined with direct load control has been changed.
- The technologies to be included in the test cells has also been altered.

We now describe each of these in turn.

7.3.1 Choice of tariff to accompany Direct Control

The original bid proposed to overlay the Direct Control tariff on the Restricted Hours proposition. Under this proposal, customers would be provided with the following package:

- a time of use tariff;
- automated control of key loads on a daily basis through the Restricted Hours proposition, with override; and
- occasional direct control of key loads without override.

However, during the development of this proposition it was decided instead that it would be more useful to combine the direct control element with a standard (or flat) tariff only.

This is based on the hypothesis that customers on the Restricted Hours tariff will tend to be using their key loads less at peak times than the average customers. Allowing interruption of the load of customers who have already shifted their use away from peak will have limited impact on distribution network costs (i.e. discretionary load will already have been moved). It was therefore agreed that it would be more useful to combine Direct Control with a flat tariff to target the peak load of those customers who did not wish to take up the Restricted Hours or Time of Use propositions.

Rather than being seen as a complement to the Restricted Hours proposition, therefore, the Direct Control proposition can be seen more as substitute, and as more suitable for those to whom time of use tariffs are not attractive.

7.3.2 Technology choice

Changes have been made to the general load and heat pump test cells, and the electric vehicle test cell will now be omitted.

General load

The original bid set out that the Direct Control general load test cell would cover:

- white goods and hot water heating for domestic customers; and
- electric cooling systems and refrigeration for SMEs.

As set out in Section 6, it has been decided to narrow the scope of technologies to be included in these cells to ensure robust learning can be gained.

- **Domestic customers**. As set out in Section 4, it has been decided to fully subsidise the smart white goods for use in this test cell, on the grounds that not enough customers would be likely to purchase the required smart goods at the outset of the trial. This means that a reduced number of customers with smart goods will be included in the test cell.[70]

- **SMEs.** It was decided to focus on electric heating and cooling systems rather than refrigeration in the SME test cell. This is because there are likely to be very few SME customers with smart refrigeration systems available to join the trial.

Heat pumps

In allocating customers between test cells, it was strongly felt that customers' ability to maintain a comfortable level of heat in their homes should not be affected.

It was therefore decided that only customers with heat pumps with storage would be allocated to those test cells that entail a degree of automation (Restricted Hours and Direct Control test cells).

Research by the Rolton Group suggests without any pre-charging of storage, the heat pump can be turned down for 30 minutes without significantly impacting on comfort levels. Since a notice period will not be given for interruptions under this tariff, the Direct Control proposition is therefore likely to only interrupt customers' use for a maximum of 30 minutes.

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70 Analysis by British Gas suggests that if customers were expected to buy smart appliances to participate, the most optimistic scenario would result in 28 customers making these purchases, given the rate of turnover in white goods and the fact that these tend to be a distress sales. The decision was therefore made to fully subsidise 75 white goods for inclusion in this test cells.

Electric Vehicles

Electric vehicle customers are unlikely to be charging their vehicle at the time when interruptions under the Direct Control tariff would be called. Since the majority of electric vehicle customers are likely to be on time of use tariffs, under business as usual conditions, they are unlikely to be charging their vehicles at peak time, since these tariffs incentivise customers away from such charging. The value of them accepting interruptions in their use during peak time is therefore not likely to be high.

Given the likely severe restrictions on electric vehicle participants to the trial, it was decided to exclude this test cell from the trial.

7.4 Summary

The aim of Direct Control proposition is to test customers' behaviour in response to the occasional interruption of the load of specific appliances, without the possibility of overriding these interruptions. This type of control can allow reinforcement costs at HV level to be deferred.

Customers would receive an annual payment for accepting these interruptions corresponding to the value to networks of deferring HV investment. Northern Powergrid has developed a methodology for assessing the value associated with moving demand based on the Common Distribution Network Charging Methodology[71] and the emerging EHV Distribution Charging Methodology. This analysis suggests a value of £30/kW/year can be used to estimate the value of occasional direct control of loads, assuming this intervention would be focussed on the parts of the network where the value of implementing it is at the higher end.

The value to a customer of accepting a Direct Control proposition will depend on the size of load associated with the appliances that they have available for interruption. These values range from <£0.20/year for cold appliances to £15/year for hot water heating. Based on these values, it was decided to exclude cold appliances from this test cell.

The technologies held by SME customers are much more diverse. British Gas developed a pragmatic approach to assessing the value of interrupting their loads. This is based on the assumption that interrupting the load of SME customers will allow a portion of the distribution network costs associated with supplying electricity to them to be saved. Applying this methodology results in a discount

71 http://www.energynetworks.org/electricity/regulation/structure-of-charges-cdcm/common-distribution-charging-methodology.html

of 2% in bills to Direct Control SME customers, who can allow 20% of their load to be interrupted. A proportionately smaller discount will be given where customers can reduce a smaller amount of load.

The Direct Control tariff is likely to have the greatest value when applied to those who usually would use their technologies at peak time. It was therefore decided to combine Direct Control with a standard (flat) tariff, rather than overlaying it on a Restricted Hours tariff, which already encourages load-shifting.

8 Annexe: Further detail on the role of DSR

Reducing future costs and timescales for connecting new technologies is the main focus of the CLNR project. This Annexe draws on analysis by Northern Powergrid to focus in more detail on the potential for DSR to reduce distribution networks.

- It first sets out analysis of the quantities of load that may be shifted before new peaks are created.
- It then discusses the differences between LV and HV, and the implications this has for the DSR measures that may reduce costs.
- It finally discusses the importance of the confidence that can be associated with load shifting.

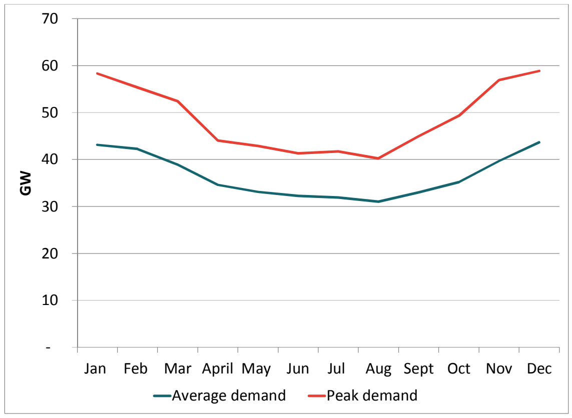
8.1 DSR potential

Figure 33, Figure 34 and Figure 35 show the shape of overall demand at GB level, based on data from 2010. These figures illustrate that there are daily, weekly and seasonal peaks in load at a system-wide level.

- **Seasonal profile.** There is a strong seasonal shape to demand, with both higher average demand, and higher peak demand, in winter time. This is driven by the fact that heating and lighting demand is higher in winter, and the penetration of air-conditioning, which causes summer peaks in other countries, is still low.
- **Weekly profile.** Demand also displays a marked pattern across the week, with much higher levels shown on Monday to Friday**.** Weekend demand is lower as much industrial and commercial (I&C) demand is only present on weekdays.
- **Daily profile.** The sample days presented in **Figure 7** show that there is also a strong daily shape to demand, with a marked peak in the early evening in winter, and the lowest demand occurring overnight. This is driven by the fact that, in the early evening, domestic demand begins to rise at a time before I&C demand has yet to drop off.

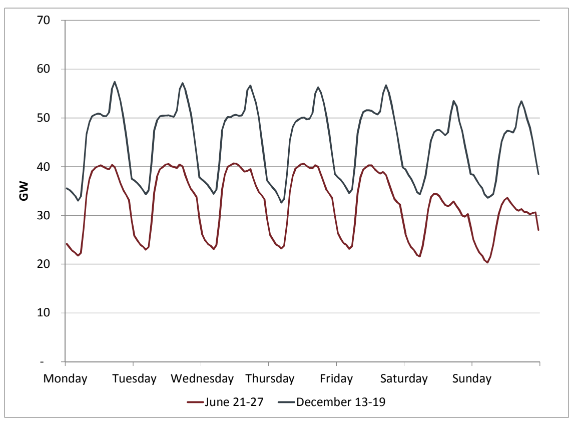
These figures therefore show that system peaks occur at winter weekday early evenings between (around 4pm-8pm). It is also clear from these figures that average demand is only 5-10% below peak demand. There is therefore likely to be useful but limited scope for flattening peaks.

Figure 33. Seasonal demand profile, 2010



Source: Frontier Economics, based on National Grid[72]

Figure 34. Weekly profile of demand, sample weeks in 2010

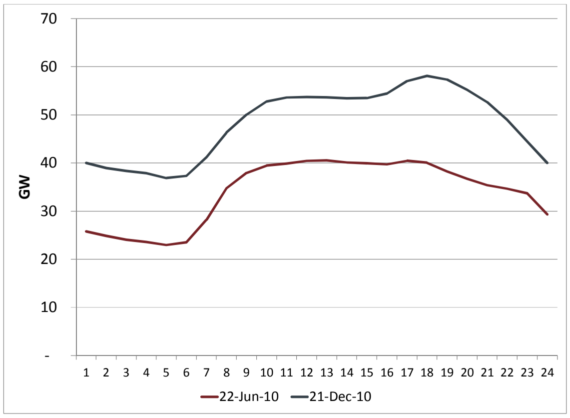


Source: Frontier Economics based on based on National Grid[73]

72 INDO, http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data/

73 INDO, http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data

Figure 35. Daily profile of demand, sample weeks in 2010



Source: National Grid[74]

Demand response at distribution network level

Some distribution networks will experience demand shapes which are different to the overall system shape. The time of use tariff propositions developed to manage demand will have to be able to reduce peaks across a range of LV and HV networks (at EHV level, a more bespoke approach can be taken).

The tariffs covered in this paper are focussed on domestic and SME customers. Large industrial customers are not included. Given this, the tariffs are therefore likely to affect the following kinds of distribution networks:

- parts of the distribution network dominated by domestic load; and
- parts of the distribution network supplying a mix of domestic and I&C loads that can be approximated by a general load curve.

Figure 36 shows Northern Powergrid's breakdown of total network demand into its component parts[75]. Total demand is broken down into a number of elements:

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74 INDO, http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data/

75 This been calibrated by Northern Powergrid using settlements data to gauge demand attributable to the domestic groups then scaling the industrial and commercial demand to match measured total peak: Specifically, profiled volumes as used for DUoS billing have been taken for 21 December 2010. These show demands of 1427MW, 398MW, and 104MW for general domestic, overnight storage and mid-day storage respectively. These have been inflated by the loss adjustment factors of 8.6%, 6.4% and 7.9% respectively for customers on the low voltage network for winter peak, night and day published in Northern Powergrid (Northeast) Final Use of System Charging Statement for 2010/11.

- **General domestic demand.** Domestic demand is low overnight (except where there are storage heaters), rises during the day and then peaks in the evening. The evening peak occurs an hour after the total network peak between about 17.30-19.30hrs.

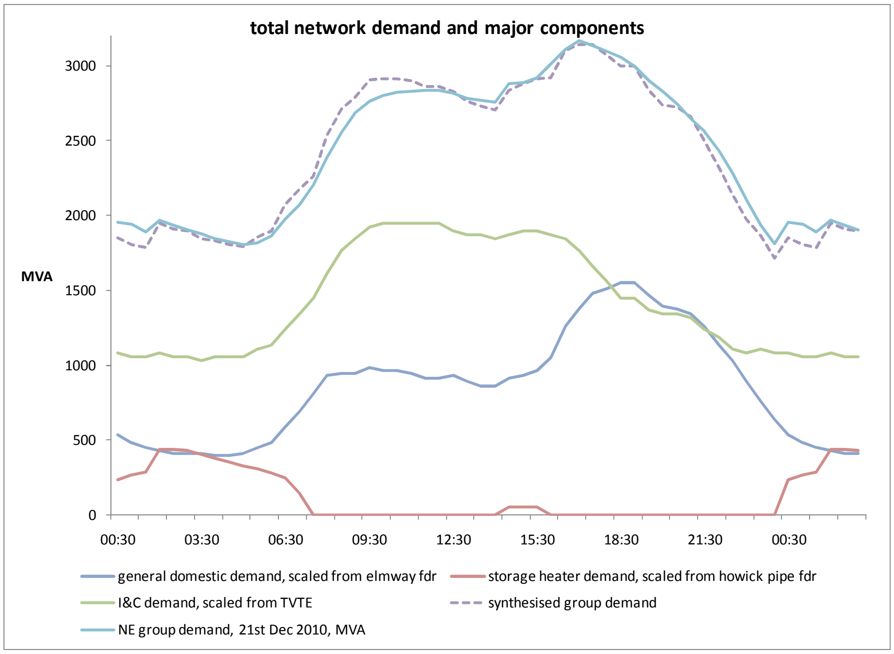
- **Industrial and commercial (I&C) demand**. I&C demand follows a reasonably flat profile over the day and falls significantly over overnight. This is due and the fact that much I&C demand shuts down after the end of the working day.

This figure illustrates that the general network peak occurs where the end of the I&C peak coincides with the start of the domestic evening peak.

Given the likely load curves for each of these two network types (as set out in Figure 36), we now set out how much demand it is likely to be possible to shift without creating new peaks. Given the strong seasonal and weekly shape of demand and the need to cut winter peaks only, this section uses the example of a winter weekday.

We first look at the case of distribution networks containing a mix of domestic and general load. We then look at distribution networks dominated by domestic load.

Figure 36. Breakdown of network demand



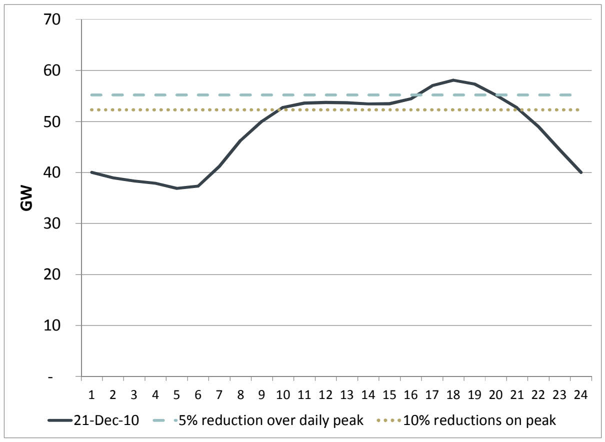
Source: Northern Powergrid

Networks dominated by a mix of loads

Figure 37 shows the impact of a 5% and a 10% shifting of peak demand on the day in 2010 with the highest demand.

As a general principle, peak daily demand should be reduced at peak times no further than the rate experienced during the day. Reducing it further would simply mean that the current daytime period becomes the new peak. Figure 37 shows that on the coldest day of the year in 2010, a reduction in the general load peak of around 5% smoothed the peak without pushing it below the levels experienced during the day. A 10% fall would push demand below the level experienced between 10h-16h and therefore some of this reduction would not be by itself be worthwhile.

Figure 37. Daily demand profile with a 5% and 10% reduction in peak



Source: Frontier Economics based on National Grid, INDO, http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data

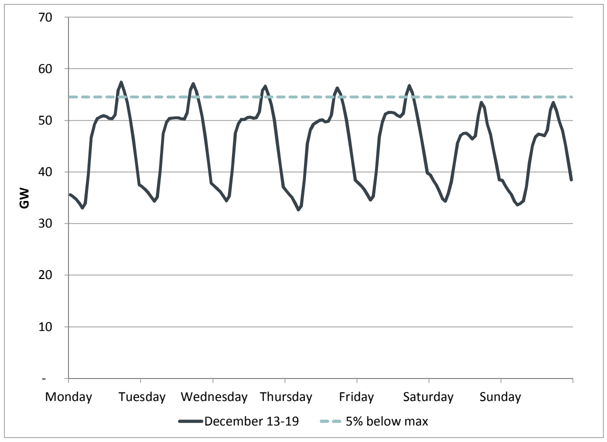
A demand reduction of 5% of general load has a number of implications for the number of times these reductions are required over the week and over the year.

- **Weekly demand profile.** Assuming the week shown is a representative winter week, Figure 38 illustrates that a 5% reduction in demand at peak times will generally be required only on weekdays. Peak demand at the weekend is likely to already be below this level.

- **Seasonal demand profile.** Figure 39 shows that a 5% reduction in demand will be required over four months of the year – November to February.

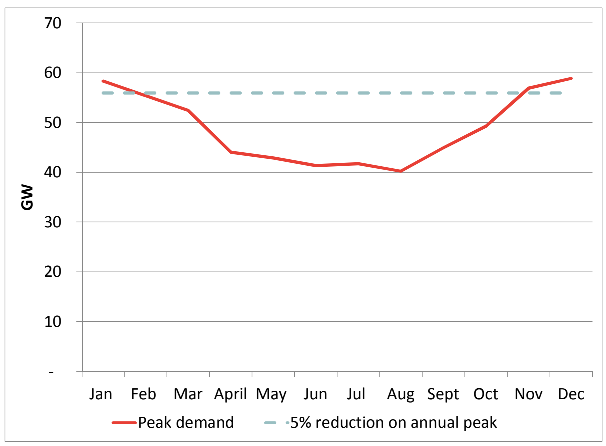
For distribution networks dominated by a mix of loads a shift of around 5% of demand from the 4pm-8pm period on weekdays for four months of the year is therefore likely to be desirable to reduce peaks.

Figure 38. Weekly demand shape with a 5% and 10% reduction in demand



Source: Frontier Economics based on National Grid, INDO, http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data

Figure 39. Seasonal demand with a 5% and 10% reduction in peak demand.



Source: Frontier Economics based on National Grid, INDO, http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data

Networks dominated by domestic load

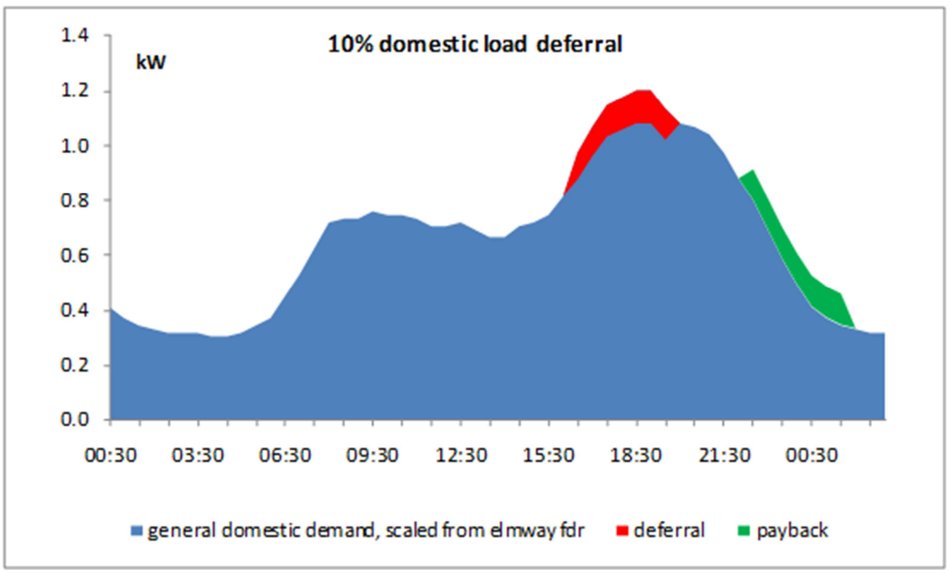
Some domestic properties will be on networks dominated by domestic load. It is therefore also important that we explore how demand response can yield benefits when only domestic load is being considered.

Figure 40 shows load for a representative residential customer as estimated by Northern Powergrid. There are two key things to note on this chart:

- Residential load is peakier than the general load. This means that a greater quantity of load can be shifted without creating a new peak.
- The residential peak also falls off less quickly than the general load peak. This means that to avoid creating a new peak, load needs to be shifted to beyond 22hrs.

The second of these points has important implications for the design of tariffs. It means tariffs should ideally be developed to ensure that where demand moves from the peak period on residential dominated feeders, it needs to be moved for a sufficient period of time so as not to create a new peak.

Figure 40. Illustration of residential load deferral



Source: Northern Powergrid

8.2 Demand response at different voltage levels

This section draws on analysis provided by Northern Powergrid to discuss the different characteristics of the low-voltage (LV) and high-voltage (HV) parts of the network. The LV and HV parts of the network differ in the following ways:

- the types of load that can impact on them; and
- the amount of spare capacity or "redundancy" they are built with.

These differences will impact on the types of demand response that is useful at each level.

The type of demand response that can reduce costs on each type of network is now set out.

HV networks

The load on HV networks is determined by the residential and SME load that is connected at LV level, as well as by the plant and load that is directly connected to HV level. Reinforcement at HV level can therefore be deferred by managing residential and SME demand to reduce peaks.

HV networks are built to withstand the impact of outages. The network is fully backed up so that it can keep functioning in the event of an outage. Reinforcement of the network of the HV network can be deferred if DSR can be called at times of network outage, instead of reliance having to be put on the back-up network.

This implies that two kinds of demand response by residential and SMEs can reduce reinforcement at HV level:

- day-in day-out reductions in peak demand over weekdays in the winter months; and
- on-demand reductions called occasionally at time of outages.

LV networks

In contrast, LV networks are built with very little spare capacity or redundancy. The load on LV networks is only affected by the customers and generation directly connected to this part of the network.

When outages occur on LV networks, customers are generally disconnected. There is therefore no role for on-demand response at this voltage level.

LV networks are also impacted by generation from PV. This causes voltage issues at LV level, once generation from PV exceeds demand.

This implies that the most important types of demand response at LV level will be the following:

- day-in day out reductions in peak demand from SMEs and residential customers over weekdays in the winter months; and
- movement of demand to when PV is generating.

8.3 Confidence

For distribution network operators to defer the reinforcement required to manage peaks, they must have some confidence that DSR will yield sufficient peak reductions. Otherwise they will not be able to deliver on their statutory duty to avoid interruption to supply by ensuring that there is sufficient capacity to meet demand[76].

However, this does not mean that all types of DSR have to be absolutely certain. The approach currently taken in planning standards[77] where generation output is unreliable (e.g. due to intermittency) is to scale down that output by an agreed percentage when calculating the contribution they are expected to make to system security. Northern Powergrid has presented an example of how this works, shown in Box 1.

Rather than requiring demand responses to be absolutely certain for investment to be deferred, a similar approach of scaling down the contribution of DSR to security of supply could be taken.

Box 2: Rating intermittent generation under current planning standards

In this example, we assume there are two demand groups. Each group has assets rated at 24 MVA, demand forecast at 26 MVA, and 4 MVA of generation capacity: Under current rules, the type of generation capacity determines whether headroom is breached:

- in the first group, the 4MVA of generation capacity is landfill gas capacity. Planning standards allow a confidence factor of 75% to be applied to this capacity, so the effective capacity is 24+(75%x4)=27 MVA, giving 1 MVA headroom; and
- in the second group, the 4MVA of generation capacity is wind capacity. Planning standards allow a confidence factor of 25% to be applied to this capacity, so the effective capacity is 24+(25%x4)=25 MVA, giving a 1 MVA shortfall.

Source: Northern Powergrid

76 Regulation 3 of the Electricity Safety, Quality & Continuity Regulations 2002

77 Specifically: Engineering Recommendation (ER) P2/6, security of supply; and Engineering Technical Report (ETR) 130, application guide for assessing the capacity of networks containing distributed generation.

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