Network impacts of energy efficiency at scale
By UK Power Networks
Undertaking the largest household appliance survey of its type, in parallel to our extensive smart meter trial, has enabled us to understand the potential benefits of energy efficient lighting and appliances, provided the mechanisms to encourage their widespread adoption are developed.
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SDRC compliance

This report is a contracted deliverable from the Low Carbon London project as set out in the Successful Delivery Reward Criteria (SDRC) section “Residential and SME Demand Side Management”
Executive Summary

This learning report outlines a higher resolution approach for evaluating the network impacts resulting from a range of possible domestic lighting and appliance energy efficiency improvements both at the household level and at scale for various future scenarios. This approach makes use of the comprehensive new smart meter and appliance ownership data collected in the Low Carbon London (LCL) project along with the latest data on appliance sales trends, efficiency performance and applicable legislation. The potential lighting and appliance energy efficiency savings quantified in this report are specific to various household types and, as such, can be applied to any geographic region within Great Britain, allowing Distribution Network Operators (DNOs) to apply the findings and methodology in this report to their specific networks. The possible reductions in future loads, and hence potential network reinforcement deferral, arising from improving lighting and appliance energy efficiency are also compared to the load reductions observed for static and dynamic Time of Use (ToU) tariff trials in Great Britain.

Household occupancy and income are strong drivers for energy savings from domestic lighting and appliances.

Lighting and appliance energy efficiency savings were found to increase with household size and income levels in line with the generally higher demand observed for these households. Within all household types, lighting and cold appliances were found to offer the greatest identifiable energy efficiency savings in 2020 and 2030 for the three scenarios developed for this analysis:

- “Reference” scenario: considers only currently implemented policies;
- “Future policies” scenario: also considers formally signed-off legislation that is scheduled to come into effect on a specified future date, and
- “Best available technology” scenario: a hypothetic scenario in which only the most efficient technologies are adopted by all households.
Lighting and cold appliances offered the greatest efficiency savings potentials

Since electricity demand from lighting tends to increase during the evening peak period, the importance of lighting appliances for efficiency savings during the evening peak period were particularly emphasised relative to their contribution to total annual savings.

**Figure 1: Appliance energy efficiency savings for different household types during the evening peak in 2020 - “future policies” scenario**

Regional energy efficiency savings are linked closely with their domestic demographic composition

When scaled up across different regions within Great Britain, it was found that the different mix of household types within each area had a significant impact on the total domestic lighting and appliance efficiency savings possible in each case. For example, the relatively high proportion of “affluent” households in Greater London, combined with the large energy efficiency savings offered by these households, means that they are estimated to account for about 57% of the reduction in evening peak demand from appliance efficiency savings by 2020 in this region under the “future policies” scenario. Moreover, almost half of the “affluent” household peak demand reduction in Greater London is predicted to come from larger “affluent” households with three or more occupants.
It is recommended that the consumer specific load and efficiency savings profiles from LCL are applied to the unique consumer demographics of each DNO.

Figure 2: Domestic lighting and appliance energy efficiency impacts on peak demand

The peak demand and total annual consumption savings from improved lighting and appliance energy efficiency by 2020 are comparable to those observed for Time of Use tariff trials.

The potential peak demand reductions from appliance energy efficiency savings (as high as 9% under the “future policies” scenario by 2020) were found to be comparable with those observed in the LCL dynamic Time of Use (dTou) trial (8%) and four UK static Time of Use (sToU) trials (between 10% and 13%). This report reveals that new appliance efficiency interventions by policy makers could realise significant additional peak demand savings (reaching a peak reduction as high as 22% by 2020 under the “best available technology” scenario). The reduction in total domestic consumption (i.e. over the entire day) from appliance energy efficiency savings (9% by 2020 under the “future policies” scenario) is also broadly comparable with that observed for the dToU trial (6%) and sToU trials (between -2% and 12%).

Overall Conclusion

The findings from LCL allow DNOs to more accurately model possible future domestic lighting and appliance energy efficiency savings within their networks at a high level of resolution. Findings in this report reveal that the load reductions available from lighting and appliance energy efficiency are potentially significant with sufficient policy support.

Further work is required to understand the mechanisms for encouraging the adoption of efficient lighting and appliances, along with the resulting costs and benefits of efficiency measures relative to other network reinforcement deferral strategies. Understanding these aspects in greater detail will not only support policy makers in formulating effective legislation in this area, but will also offer DNOs and other industry stakeholders important insights into how domestic loads are likely to change on their networks in coming years as a result of energy efficiency improvements.
Introduction

1.1 Background

Domestic lighting and appliance energy efficiency is a key element of the emissions reduction strategy for the United Kingdom (UK) [Ref. 1] and within the broader context of European Union (EU) legislation. Distribution network operators (DNOs) also consider the impacts of domestic lighting and appliance efficiency improvements when assessing future loads and planning investment within their networks.

Predicting domestic lighting and appliance energy efficiency impacts is a challenging aspect of load forecasting due to the variation in ownership patterns, technology characteristics and usage trends across different households, as well as ongoing changes to legislation, market characteristics and consumer purchasing behaviour. As such there are few current data sources which account for all these aspects when predicting lighting and appliance energy efficiency impacts across Great Britain (GB). To date, the most comprehensive and widely used source of information available to DNOs on lighting and appliance efficiency improvements has been the Market Transformation Programme (MTP) maintained by the Department for Environment Food and Rural Affairs (Defra) [Ref. 2]. The MTP efficiency projections were used in the Transform model developed by the Smart Grid Forum and also by UK Power Networks in its load growth model. However, the large MTP dataset has not been updated for several years in which time energy efficiency legislation and the efficiency of many modern appliances have changed.

To address this limitation, the Low Carbon London (LCL) trials collected comprehensive datasets on demand profiles for 5,510 households and appliance ownership patterns of 2,830 households within the Greater London area [ICL5]. In this report, these datasets and energy efficiency learnings from LCL are used to explore the lighting and appliance energy efficiency potentials of various domestic household types within GB. This report captures the impact of the latest UK and EU lighting and appliance efficiency legislation as well as the most recent data on modern lighting and appliance operational efficiencies and adoption rates. Using these datasets, this report also gives insights into how the impacts of lighting and appliance energy efficiency on domestic demand and peak loads compares to those from demand side response (DSR) market interventions such as static and dynamic Time of Use tariffs.
1.2 Scope

This report looks specifically at how the household electricity demand and appliance ownership data from LCL can be used to better understand the future impacts of energy efficient appliance uptake:

- For different domestic customer types;
- Aggregated across various geographic regions within GB;
- Aggregated across all of GB; and
- Versus the impacts of interventions such as static and dynamic Time of Use tariffs.

In this report the term “appliances” will be taken to also include lighting devices. The energy efficiency impacts examined in this report relate to those from the domestic uptake of modern efficient appliances due to the regular replacement of household appliances (sometimes referred to as appliance “churn”). The impact of current energy efficiency legislation, product replacement trends, population growth, increases in the national housing stock and changes in average appliance sizes (e.g. larger televisions) are all considered within the context of this report. Reductions in electricity consumption due to lifestyle changes or curtailment of existing household activities are not explicitly considered in this report.
This chapter provides a review of the existing DNO activities regarding load forecasting, particularly with respect to energy efficient appliance impacts. It provides the context for the current analyses and for the future recommendations.

Each DNO has the responsibility to plan for the development of its network to ensure the following:

- Sufficient capacity for organic load growth;
- A network design that provides the most reliable connection for the customer; and
- Costs are reduced as far as reasonably possible whilst maintaining the above.

To achieve these outcomes, DNOs typically employ tools to forecast future loads on their networks, taking into account the impact of population and economic growth, energy efficiency improvements and the adoption of new technologies such as Electric Vehicles (EVs), Heat Pumps (HPs), Solar Photovoltaics (PV) and wind generation. This chapter provides a review of the existing tools, processes and methodologies used by DNOs in general, and UK Power Networks in particular, to help assess future network loads, particularly in the context of appliance energy efficiency impacts.

2.1 DNO load forecasting tools

2.1.1 The Transform Model

The Transform model was developed by the Department of Energy and Climate Change (DECC) and the Office of Gas and Electricity Markets (Ofgem) Smart Grid Forum [Ref. 4] as a means of assessing the impact of low carbon technologies on distribution networks and the investment required in network reinforcement. The model is one of the key tools that DNOs have used to forecast investment in network reinforcement within their RIIO-ED1 business plans.

At the core of the Transform model is a parameterised representation of typical electricity distribution networks. Network models can be constructed on the basis of standard network types, which describe different topology (radial or meshed), construction (underground or overhead) and typical features of networks in areas of differing geography (urban, rural or suburban). A network area is modelled by combining these standard network types in appropriate combinations to reflect the real network configurations.
The standard networks are also described in terms of the number of customers connected and the typical mix of customer types. The customer types include domestic buildings of different sizes and non-domestic buildings of different use types. Load on the network is modelled as an aggregation of the load related to each of these customer types on the standard networks. Factors such as floor area, energy efficiency condition, appliance usage patterns and environmental factors including the average, peak and minimum temperatures in the area of interest are also considered in the network load modelling.

The major driver for development of the Transform model was to provide the DNOs with a means of assessing the potential impact of the low carbon transition on their networks. A scenario-based approach is used to describe a range of potential outcomes regarding the uptake of low carbon technologies, such as PV, heat pumps and electric vehicles, and rate of adoption of energy efficiency improvement. The scenarios incorporated into the model were also developed by the Smart Grid Forum, and are based on projections by DECC and the Department for Transport (DfT) of the requirements for UK carbon reduction objectives to be achieved. These national level uptake scenarios have been disaggregated to projections of the uptake of each technology at the level of individual feeders, enabling scenarios to be constructed that are specifically tailored to each licence area.

The Transform model is principally a tool to quantify the level of investment required in distribution networks to meet the challenge of increasing connections of low carbon technologies. The required investment is calculated on the basis of the modelled increase in network load and an assumed distribution of available headroom across network assets. The model is able to select actions to solve network constraints from a database of potential solutions, including both conventional and smart approaches to either reinforcing networks or managing demand. The model selects solutions on the basis of a merit order, which ranks appropriate solutions on their cost-effectiveness. In this way the model is able to estimate the least cost approach to coping with the load growth associated with different scenarios for low carbon technology uptake. The model also allows different strategies to be compared, for example conventional (or business-as-usual) versus smart reinforcement strategies. The overall investment required and extent to which each of the available solutions have been adopted are each outputs of the model that DNOs can use in their RIIO-ED1 business planning.

2.1.2 The Element Energy Load Growth Model

While the Transform Model provides a common approach for DNOs to assess the scale of impact of load growth related to low carbon technologies and energy efficiency on their networks, the generalised parametric methodology means it faces some limitations in capturing the nuances of individual distribution networks at a high degree of spatial, asset and demographic resolution. For this reason, a number of GB DNOs have also developed load forecasting tools that are specific to their particular licence areas. UK Power Networks contracted Element Energy to develop such a model for its licence areas, which is capable of forecasting load growth resolved to the level of individual distribution substations. To do this, the Element Energy Load Growth (EELG) model combines detailed data on the mix of domestic properties and business types, resolved to postcode sector level, with an accurate representation of the networks, in terms of the locations and connectivity of assets, in each licence area. This allows the load connected to each substation to be modelled on the basis of a highly resolved understanding of the customer mix. The EELG model also incorporates a comprehensive set of scenarios for future load growth, based on:

- Population and economic growth along with evolution of the building stock;
- Energy efficiency improvements in the domestic and commercial & industrial sectors; and
- Uptake of a broad range of low carbon technologies such as electric vehicles, heat pumps (domestic and non-domestic), wind power, solar photovoltaics and domestic micro-generation.

These scenarios are informed by a combination of historical trends, government projections and Element Energy’s modelling of the uptake of energy efficiency measures and low carbon technologies [Ref. 4]. These models forecast the impact of differing assumptions regarding financial incentive regimes, technology costs, performance improvements and energy costs on the rate of uptake, based on a detailed understanding of consumer purchasing behaviour (informed by extensive consumer surveys). A simplified schematic of the Element Energy Load Growth Model is shown in Figure 3.
The following are key outputs of the EELG model, which can be forecast for each substation and at each voltage level across the licence areas:

- Annual peak demand (MW);
- Total annual consumption (GWh);
- 24 hour demand profiles (MW) for a selected month and year, and
- Annual generation capacity connected (MW) for PV, wind and Combined Heat and Power (CHP) along with their 24 hour generation profiles for each desired month and year.

Figure 4 shows two example output charts, which can be generated at different network levels, i.e. each of the UK Power Networks licence areas, grid supply points, primary and secondary substations.
Figure 4: Example outputs from the Element Energy Load Growth Model.

a) Evolution of peak load over time at network level

b) Daily load profile forecast for 2030, at network level.
2.1.2.1 How the Element Energy Load Growth Model feeds into other UK Power Networks planning tools

While the EELG model generates a forecast of future loads (load profiles, peak loads and annual consumption), it does not provide any forecasts of the level of investment required to reinforce the network to cope with the increasing load. In order to plan future expenditure, UK Power Networks use the load growth forecasts provided by the EELG model as inputs to two further planning tools – the Planning Load Estimates (PLE) model and the Imperial College London’s (ICL) Load Related Expenditure (LRE) model (see Figure 5) [Ref. 5].

The PLE is a site specific model that UK Power Networks use as a “first pass” method of identifying substations that are likely to require demand-driven expenditure given a certain overall load growth scenario. Based on assessment of the demand at a substation (net of firm generation) and the available headroom, the PLE model will identify substations that are at or close to capacity. The substations that are flagged through this process will then normally be subjected to more detailed analysis.

The LRE model was developed for UK Power Networks by Imperial College London as a means of rapidly assessing the impact of different load growth scenarios on power flows at all voltage levels across the networks. The LRE model applies year-on-year load growth factors provided by the EELG model to historic maximum demand data, as measured on each high voltage circuit, and then uses optimal power flow modelling to flag overloaded assets. Using detailed cost data, it is then possible to generate a cost-profile for the specific load growth scenario. Hence the combination of the EELG and LRE models enables UK Power Networks to derive multiple potential load growth scenarios and generate associated load related expenditure forecasts for each scenario. These two models constitute a powerful set of tools for assessing the sensitivity of investment planning to varying load growth assumptions, for business planning purposes.

**Figure 5: A schematic view of the UK Power Networks network planning methodology**

- **A: Load growth forecasting**
  - Assumptions Input
  - Load growth modelling

- **B: Network investment planning**
  - Identify network investment requirements
  - Identify and compare intervention options
  - Evaluate and select intervention options
  - Finalise Network Asset Management Plan

**Models used at UK Power Networks**
- Element Energy model
- Planning Load Estimates (PLE)
- Imperial College London Load Related Expenditure (LRE) model
- Transform model

**Key business questions**
- What are the future drivers of load growth on the network?
- What is the expected increase in load on the network?
- Which assets are impacted by the projected load growth?
- When will the assets be impacted?
- How are the assets impacted?
- What are the options to address the impact?
- What is the best option to address the impact?
- What interventions should be executed and when?
2.2 Standards and monitoring

For DNO load forecasting, the industry does not prescribe specific future technology uptake and energy efficiency scenarios. Rather, DNOs select the network planning assumptions that best fit their particular networks and the consumers and technology adoption patterns that are most relevant to their regions.

The Transform Model (see Section 2.1.1) offers some opportunity for standardisation of load forecasting across DNOs. However, in practice, many DNOs opt for higher resolution and more network-specific load forecasting tools to obtain a more accurate indication of future loads within their licence areas (section 2.1.2).

While there are no prescribed scenarios that dictate the assumptions required around appliance energy efficiency impacts on load forecasts, in practical terms, the limited availability of data in this area has meant that most load forecasting tools make use of the same dataset and scenario assumptions. This energy efficiency dataset is the Market Transformation Programme (MTP), managed by Defra, and maps out future energy efficiency improvements across a variety of appliance types under several scenarios. This dataset was previously updated in 2010.

Since there have been no major updates to the MTP dataset since 2010, there have been limited options for updating the energy efficiency assumptions within the various DNO load forecasting tools. The new smart meter and appliance ownership data collected from the LCL project offer a valuable opportunity to update this aspect of DNO load forecasting tools. With the emergence of datasets like those from LCL, it is now possible to develop an updated range of regionally specific energy efficiency scenarios.

2.3 Policy landscape

There is a significant potential for the abatement of household electricity consumption through uptake of energy efficient appliances. This section aims to present the national and European regulations impacting this uptake, and to give an overview of their desired effects in terms of evolution of sales, improvement of technologies, and resulting evolution of electricity consumption by domestic consumers. In the context of the LCL project, the discussion focuses on the measures concerning replacement of light bulbs and appliances with more energy efficient technologies.

2.3.1 Supplier obligations

Since the launch of the Energy Efficiency Standards of Performance (EESoP) scheme in 1994 and its successor, the Energy Efficiency Commitment (EEC) launched in 2002, three other schemes have been put in place in the UK with the common goal of encouraging improvement of household energy efficiency to generate savings in electricity consumption and carbon emissions. The EEC and EESoP both focused particularly on low income consumers, categorised as a priority group, and this focus was also evident in the subsequent schemes: the Community Energy Saving Programme (CESP), the Carbon Emissions Reduction Target (CERT), and the current scheme called the Energy Company Obligation (ECO) [Ref. 6]. The principle of these programmes is to require large energy companies to deliver energy efficiency measures to domestic properties. To ensure that the objectives are met, quantitative evaluation means are defined to record the measures that are put in place (e.g. in the case of insulation renovations, targeted U-values [Ref. 7] are specified depending on wall types, wall thicknesses, and ages of properties). Within the ECO programme, energy companies report every month to Ofgem on the measures installed in the previous month.

The energy efficiency measures delivered during the EEC programme (which ran from 2002 to 2008) mainly covered insulation and heating systems improvements, and replacement of light bulbs and other appliances with more energy efficient alternatives. Almost 12% of the total energy savings were achieved through lighting measures, with a total of 30 different schemes to promote energy efficient lighting. The EEC allowed the uptake of Compact Fluorescent Lamps (CFLs) to be considerably accelerated, in particular through the free distribution of CFLs. As a result, a total of over 100 million incandescent light bulbs were replaced by CFLs. Concerning the measures for appliance replacements, the EEC covered a wide range of appliances from televisions to cooking (in particular kettles), cold and wet appliances (fridges, freezers, fridge-freezers, dishwashers and washing machines). During the second phase of EEC, over 8 million cold and wet appliances were replaced with A, A+ and A++ rated options (as defined under the European Energy Labelling Scheme), which accounted for 34% of the energy savings delivered by appliances measures. Subsequently, from 2008 to 2012, the CERT programme also targeted efficient light bulbs and appliances, delivering almost 305 million lighting measures by the end of the project – mainly CFLs, but also some halogens, luminaires and Light-Emitting Diodes (LEDs) – along with a number of measures promoting replacement of cold appliances with A+ or A++ rated products. The current scheme ECO covers a
wide range of measures, focusing principally on insulation (wall insulation, loft insulation, double glazing, insulated doors, hot water cylinder jacket insulation, etc.), heating system improvements (replacement of inefficient boilers, installation of electric storage heaters and heating controls, upgrade of district heating connections, etc.) and micro-generation (heat pumps, biomass boilers, photovoltaic, micro wind and micro hydro). There is no particular focus in ECO on lighting and appliances.

2.3.2 Code for Sustainable Homes

The Code for Sustainable Homes also takes into account the energy efficiency of products that are installed in new build homes. It uses a star system to rate the overall sustainability performance of a new home (on a scale of one to six), against nine categories: depending on the requirements that households meet in these nine categories, a certain number of credits are attributed, and the total number of credits correspond to a number of stars. Among these nine categories, the “Energy and CO2 Emissions” category gives credits for the installation of some energy efficient white goods (e.g. refrigerating appliances which have an energy rating better than A+ and tumble-dryers or washer-dryers which have at least a B rating) and of efficient lighting (e.g. for external space lighting with dedicated energy efficient fittings and appropriate control systems).

2.3.3 Product Directives

At the European level, the Energy-related Products (ErP) Directive [Ref. 8] was adopted in 2009 (following on from the Eco-Design Directive), which defined a common framework for European countries to promote the rollout of energy efficient products. Application of this legislation in the UK is ensured by the National Measurement Office, which aims at long term compliance through market surveillance and business support. The main difference between this regulation and the preceding European regulation - the Eco-design Directive - is that the Energy-related Products Directive takes into account a larger number of product types, including products that do not directly consume energy but can contribute to energy saving (e.g. water using devices, windows, building insulation products, etc.). Whilst it is estimated that 80% of all product-related environmental impacts are determined during the design phase of a product [Ref. 9], this directive takes into account the various stages of a product lifetime, considering its impact on the environment during production, distribution, use and end-of-life. It also imposes labelling of products based on common energy rating definitions in order to raise consumers’ awareness about energy efficiency. Figure 6 [Ref. 10] shows the common elements to these labels.

Figure 6: Common elements found on EU energy labels [Ref. 11]

2.3.3.1 Lighting

In terms of lighting legislation, the Energy-related Products Directive established ecodesign requirements for non-directional household lamps in order to achieve a shift toward use of more energy efficient light bulbs while also ensuring improvement of functional properties. Requirements are to be met over six stages between 2009 to 2016, which correspond to a progressive phase-out plan for non-efficient technologies, and which require new devices to comply with a number of criteria related to efficacy (e.g. maximum power by luminous flux) and functionality (e.g. lifetimes related criteria). The table 1 [Ref. 12] shows the detailed phase-out plan and the introduction of the two levels of functionality requirements.
Table 1: Phase-out plan of inefficient lighting

<table>
<thead>
<tr>
<th>Requirement for all lamps - minimum energy label class [Ref. 14]</th>
<th>Phase out planning</th>
<th>Requirement for all lamps - minimum energy label class</th>
<th>Phase out planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-clear lamps</td>
<td>Phase out planning</td>
<td>Clear lamps</td>
<td>Phase out planning</td>
</tr>
<tr>
<td>Incandescent</td>
<td>Halogen</td>
<td>CFL / LED</td>
<td>Incandescent and conventional halogen</td>
</tr>
<tr>
<td>2009</td>
<td>A (and B for certain lamps)</td>
<td>phase out</td>
<td>phase out</td>
</tr>
<tr>
<td>2010</td>
<td>A (and B for certain lamps)</td>
<td>phase out</td>
<td>phase out</td>
</tr>
<tr>
<td>2011</td>
<td>A (and B for certain lamps)</td>
<td>phase out</td>
<td>phase out</td>
</tr>
<tr>
<td>2012</td>
<td>A (and B for certain lamps)</td>
<td>phase out</td>
<td>phase out</td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td>Introduction of a second level of functionality requirements (LEC are exempted)</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td>Review of the regulation</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>A (and B for certain lamps)</td>
<td>phase out</td>
<td>phase out</td>
</tr>
</tbody>
</table>

2.3.3.2 Refrigerating and wet appliances

The Energy-related Products Directive also contains a number of ecodesign requirements for household refrigerating appliances (refrigerators, freezers, and fridge-freezers) and wet appliances (washing machines, dishwashers and tumble dryers). The rollout of more efficient technologies is planned through several phases from 2009 to 2015 and the targets to be reached by manufacturers are measured in terms of an Energy Efficiency Index (EEI). These indicators are defined by the Energy-related Products Directive and they enable suppliers and consumers to estimate product energy efficiencies (in terms of annual power consumption relative to a reference consumption level). Each EEI takes into account several energy efficiency related criteria, and they are defined specifically for each type of appliance.

For instance, the EEI for cold appliances is calculated from daily energy consumption within certain conditions and product compartment details. For example, Table 2 shows how the maximum value of the EEI of a particular cold appliance category should decrease gradually from 2010 to 2015 [Ref. 12].
Table 2: Phase-out of inefficient refrigerating appliances

<table>
<thead>
<tr>
<th>Application date</th>
<th>Energy Efficiency Index (EEI) of compression-type refrigerating appliances</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 July 2010</td>
<td>EEI &lt; 55</td>
</tr>
<tr>
<td>01 July 2012</td>
<td>EEI &lt; 44</td>
</tr>
<tr>
<td>01 July 2014</td>
<td>EEI &lt; 42</td>
</tr>
</tbody>
</table>

A summary of the three main policy areas described above is provided in Table 3.

Table 3: Summary table of main policies

<table>
<thead>
<tr>
<th>Policy name</th>
<th>Years active</th>
<th>Key features</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE SoP, EEC, CESP, CERT, ECO</td>
<td>1994 - present</td>
<td>Delivery of energy efficiency measures to domestic properties</td>
<td>Improvement of household insulation, heating system, and appliance energy efficiency, rollout of micro-generation technologies, etc.</td>
</tr>
<tr>
<td>Energy-related Products (ErP) Directive</td>
<td>2009 - present</td>
<td>Planning of the rollout of energy efficient products</td>
<td>Rollout of more energy efficient domestic products, covering categories from electronic devices, computing devices, wet and cold appliances, lighting, cooking, etc.</td>
</tr>
</tbody>
</table>

2.4 Updates to the Element Energy Load Growth Model

The Element Energy Load Growth model was introduced at high-level in Section 2.1.2. In this section a more detailed discussion of the assumptions used to derive load growth projections in the EELG model is provided. We then introduce the modifications that have been made to the EELG model in order to integrate the new data that has become available through the LCL project.

2.4.1 Original assumptions used in the Element Energy Load Growth Model

This section outlines the original load assumptions that were used in the EELG model before the new dataset from the LCL project became available (domestic smart meter data and appliance ownership information along with load profiles for HPs and EVs). For a description on how LCL data was implemented, please refer to Section 2.4.2.

2.4.1.1 Demand and load profile assumptions

The original load assumptions used in the EELG model are tabulated below, in terms of the conventional domestic and non-domestic customer segments (Table 4) and then the new low carbon technologies that are expected to drive significant load growth are described (Table 5). It is worth noting that the EELG model also considers electricity generation from distributed PV, micro Combined Heat and Power and wind power, however since these aspects of the model are not relevant to this report, they are not covered here.
Table 4: Demand and profile related assumptions for existing domestic and non-domestic loads used in the original EELG model.

<table>
<thead>
<tr>
<th>Domestic sector</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing Domestic and Non-Domestic Load Assumptions</strong></td>
<td></td>
</tr>
<tr>
<td><strong>10 domestic building types (referred to here as consumers) are defined, based on house type, rural-urban character, property age and availability of a gas connection. Specific annual electricity requirements are calculated for:</strong></td>
<td></td>
</tr>
<tr>
<td>• Space heating;</td>
<td></td>
</tr>
<tr>
<td>• Hot water heating;</td>
<td></td>
</tr>
<tr>
<td>• Lighting;</td>
<td></td>
</tr>
<tr>
<td>• Cooking; and</td>
<td></td>
</tr>
<tr>
<td>• All other electric appliances.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Commercial, industrial and public sector</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing Domestic and Non-Domestic Load Assumptions</strong></td>
<td></td>
</tr>
<tr>
<td><strong>14 consumer types are defined, with specific annual demands for:</strong></td>
<td></td>
</tr>
<tr>
<td>• Commercial office space;</td>
<td></td>
</tr>
<tr>
<td>• Industrial;</td>
<td></td>
</tr>
<tr>
<td>• Retail;</td>
<td></td>
</tr>
<tr>
<td>• Warehouses;</td>
<td></td>
</tr>
<tr>
<td>• HospitalityFurther and higher education;</td>
<td></td>
</tr>
<tr>
<td>• Leisure;</td>
<td></td>
</tr>
<tr>
<td>• Health;</td>
<td></td>
</tr>
<tr>
<td>• Other service sector;</td>
<td></td>
</tr>
<tr>
<td>• Other government;</td>
<td></td>
</tr>
<tr>
<td>• Schools;</td>
<td></td>
</tr>
<tr>
<td>• Special industrial;</td>
<td></td>
</tr>
<tr>
<td>• Communication and transport; and</td>
<td></td>
</tr>
<tr>
<td>• Government estate.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 5: Demand and profile related assumptions for emerging low-carbon technologies in the original EELG model

<table>
<thead>
<tr>
<th>Heat pumps (HP), domestic</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-Carbon Technology Assumptions</strong></td>
<td><strong>Data Sources</strong></td>
</tr>
<tr>
<td>Three types of domestic HPs</td>
<td>Annual demand for space and hot water heating is derived from Element Energy’s characterisation of the 10 domestic household types. Domestic HPs follow a set of monthly profiles which represent Time of Use heating demand. These profiles are based on data collected under the Carbon Trust micro-CHP field trials. The LCL trials also collected load profile data for heat pumps which have been incorporated into the EELG model in this project (as discussed in Section 2.4.2). However, since this report is focused specifically on energy efficiency impacts for existing appliance loads, the impact of future wider-scale adoption of heat pumps was turned off in the model when producing the outputs for this report to isolate appliance energy efficiency impacts only. Load projections for heat pumps are covered in LCL report Report B5.</td>
</tr>
</tbody>
</table>

### Heat pumps (HP), non-domestic

<table>
<thead>
<tr>
<th><strong>Low-Carbon Technology Assumptions</strong></th>
<th><strong>Data Sources</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>One average representation of non-domestic HPs</strong></td>
<td>Non-domestic space and hot water heating demand is derived using the same methodology as electricity demand, as described in Table 4 (i.e. using VOA floor space data and energy consumption benchmark figures). Non-domestic HP load is assigned to a set of monthly profiles. The demand profile shape is based on a simple set of occupancy assumptions for non-domestic premises types.</td>
</tr>
</tbody>
</table>

### Electric vehicles (EV)

<table>
<thead>
<tr>
<th><strong>Low-Carbon Technology Assumptions</strong></th>
<th><strong>Data Sources</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Three types of electric vehicles are considered:</td>
<td><strong>Data Sources</strong></td>
</tr>
<tr>
<td>- Battery electric vehicles</td>
<td>EV performance and operational characteristics are taken from an Element Energy analyses for the Low Carbon Vehicle Partnership and Transport for London.</td>
</tr>
<tr>
<td>- Plug-in hybrid electric vehicles</td>
<td>The EV demand follows a profile that is based on detailed trip statistics data (from the Department for Transport’s National Travel Survey) and takes into account when people finish a journey, the consumption during that journey and the likelihood of a charging event after a journey.</td>
</tr>
<tr>
<td>- Range-extended electric vehicles</td>
<td>The LCL trials also collected load profile data for electric vehicles which have been incorporated into the EELG model. However, since this report is focused specifically on energy efficiency impacts for existing appliance loads, the impact of future wider-scale adoption of electric vehicles was turned off in the model when producing the outputs for this report to isolate appliance energy efficiency impacts only. Load projections for electric vehicles are covered in LCL Report B2 [Ref. 16].</td>
</tr>
</tbody>
</table>
2.4.1.2 Projections for future load levels

After establishing the baseline load for each of the sectors (Table 4) and technologies (Table 5), the EELG model builds future projections of load in each sector based on the user-selected scenario settings. The approach and assumptions used in the EELG model to build these future load projections are outlined below.

- **Domestic**
  The load model projects the overall growth rate and demolition rate of the housing stock in each local authority covered by the networks. The number of old properties declines over time, while new houses are built to drive the overall growth in the stock. The model includes three scenarios for the growth of the housing stock (historic, low growth or local government’s target) and also allows the user to define stock growth and demolition rates. The condition of the “existing” homes, i.e. those present in the base year of the model, is assumed to improve over time due to the adoption of thermal energy efficiency measures, such as wall insulation, double-glazing etc. (three different scenarios for the rate of improvement of the exiting stock are included). Future projections of the domestic load also depend on the change in domestic appliance stock, which is addressed in Section 2.4.1.2.

- **Commercial, industrial and public**
  The future demand of the commercial, industrial and public sectors is defined by the economic growth rate and the average sector efficiency. Economic growth can be set manually or pre-set growth scenarios of 2% or 3% per year can be selected. The annual industrial and commercial efficiency improvements are defined by one of three Element Energy scenarios (low, baseline, high) that are based on data from the UK Office of National Statistics.

- **Heat pumps**
  The uptake of domestic heat pumps is generated using an external model developed by Element Energy. The model uses willingness-to-pay curves derived from consumer surveys to forecast the proportion of the decision-makers (i.e. those households replacing their heating system) that will purchase a heat pump given a particular pay-back (compared to their existing heating system). The installation of HPs causes an increase in electricity demand, according to the HP specifications. Conversely, HP uptake will reduce the conventional demand for electric heating (for the consumers that switch from primary electric heating to HPs). This uptake model has been used to forecast uptake over the period to 2030 – the period that the Renewable Heat Incentive is assumed to support the heat pump market. Three Element Energy uptake scenarios are available: low, medium and high.

DECC has also developed a set of scenarios for the uptake of heat pumps, electric vehicles and photovoltaics at the GB level. For each technology, DECC has developed three scenarios: low, medium and high uptake. As part of the work of the Smart Grid Forum, these national scenarios have been disaggregated to provide forecasts of uptake in each of the UK Power Networks licence areas. In addition to the Element Energy uptake scenarios for domestic HPs, there is a set of three DECC scenarios, which define the uptake of both domestic and non-domestic HPs.

In the longer term, post-2030, it is assumed that the financial incentives for heat pumps will have expired and the market for the technology will either continue to grow based on economic competitiveness or the market will stall. Again, the post-2030 uptake scenario can be set to either low, medium or high.

There is a further option in the model to cluster the uptake of HPs based on the building type, willingness to pay, attitudes to the environment and disposable income of various household types. The building and occupant characteristics used to develop this clustering option were taken from Experian data resolved to the postcode sector level.

- **Electric vehicles**
  Similarly to HPs, six uptake scenarios are available in the EELG model. Element Energy established three uptake scenarios that are based on the growth of the total car parc and the uptake of EVs. The growth of the car parc [Ref. 17] ranges from low growth as a consequence of policy interventions to high growth caused by strong population increase. The number of EVs is determined as a percentage of the overall car parc. This percentage was derived in an external Element Energy model, which predicts vehicle sales based on assumptions of vehicle availability, performance, and consumer behaviour preferences. The market for ultra-low carbon vehicles and electric drivetrains is underpinned by European legislation on fleet averaged emissions in 2020. In addition to the Element Energy scenarios, there is a set of three DECC scenarios for EV uptake.
2.4.1.3 Energy efficiency considerations

In the original version of the EELG model, the projection for the demand of the domestic sector depends on the evolution of the housing stock, which is represented by a defined set of scenarios. These scenarios are based on the Energy Saving Trust Housing Energy model developed by Element Energy, along with the scenarios published by Defra in 2010 within the Market Transformation Program (MTP) [Ref. 18].

The uptake of energy efficient appliances is defined for lighting, cooking and other appliances (see Figure 7). Energy efficient appliance uptake scenarios were originally based on MTP scenarios, as follows (for further details on each of the MTP scenarios and the specific policies they cover, please refer to Defra’s “Saving Energy Through Better Products and Appliances” [Ref. 19] report):

- “Reference” scenario: A “business as usual” scenario that projects energy consumption per appliance based on the impact of all agreed and formally signed-off policies, but assuming that no new policies are implemented;
- “Future policies” scenario: Describes how the domestic energy consumption would evolve if a new set of policies were implemented. This includes expected new policies as well as likely future revisions to existing policies;
- “Best available technology” (BAT) scenario: This is a hypothetical scenario of what would happen if only the best available technologies [Ref. 20] of the current (and projected future) market were available, and
- “Zero improvement” scenario: This is another hypothetical scenario in which there is no efficiency improvement, ignoring even the agreed and formally signed-off policies that are covered by the “reference” scenario.

MTP data for the scenario above was used to derive the appliance efficiency improvements used in the EELG model (shown in Figure 7). The projections shown in Figure 7 start in 2009 because this was the start year for the most recent MTP efficiency projections available. In addition to the change in appliance efficiency, the EELG model also captures MTP data on increases in the number of appliances per household.

Figure 7: Energy efficiency savings per appliance in the original EELG model scenarios.
2.4.2 Updates to the Element Energy Load Growth Model based on the new data from LCL

This section provides an overview of the changes made to the EELG model based on the new data resulting from the LCL project. On the basis of the findings of the LCL project, a complete re-modelling of the domestic demand calculation and the impact of efficient appliance uptake has been implemented. The sections of the EELG model that are impacted by these changes are shown in green in Figure 8.

Figure 8: Simplified schematic showing (in green) the sections of the Element Energy Load Growth Model that were updated based on the new data from LCL.

<table>
<thead>
<tr>
<th>Data input / sub-models</th>
<th>Circuit data</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willingness to pay models</td>
<td>Building energy model</td>
<td>MWh/yr &amp; MW demand forecasts at each voltage level</td>
</tr>
<tr>
<td>Technology uptake rates</td>
<td>Distribution substations</td>
<td>Calibrate to DNO’s historic load data</td>
</tr>
<tr>
<td>Energy efficiency improvement</td>
<td></td>
<td>Seasonal demand variation at each voltage level (by month and peak day)</td>
</tr>
<tr>
<td>Consumer type demands</td>
<td>Primary substations</td>
<td>Daily load profiles (by month and year)</td>
</tr>
<tr>
<td>Technology clustering data</td>
<td>Grid Supply Points</td>
<td>Annual embedded generation capacity (by month and year)</td>
</tr>
<tr>
<td>DSR potential and flexible load</td>
<td></td>
<td>Daily embedded generation profiles (by month and year)</td>
</tr>
<tr>
<td>Building stock data</td>
<td>LV connections model</td>
<td></td>
</tr>
<tr>
<td>LV connection data</td>
<td>Large renewable connections</td>
<td></td>
</tr>
<tr>
<td>Growth rates / economic activity</td>
<td>HV connected I&amp;C load</td>
<td></td>
</tr>
</tbody>
</table>

2.4.2.1 Domestic load profile assumptions

The LCL smart meter trial data was used to produce domestic consumption profiles for nine distinct household types. These nine LCL household types were determined using occupancy and Acorn geodemographic data [Ref. 21] obtained for each of the LCL trial households (this analysis was performed by Imperial College London – see Section 3.2 for further details). The EELG model has been constructed using geodemographic data from Experian (referred to as Experian Mosaic Groups [Ref. 13]) to characterise households, at postcode sector level resolution, in terms of demographics and building attributes (e.g. type of dwelling, age, tenure etc.). Therefore, it was necessary to develop a mapping procedure to correlate the Experian Mosaic Group data within the EELG model to the Acorn household types [Ref. 22]. Combining this with high resolution Experian data on household occupancy levels, it was possible to determine the distribution of the nine LCL household types at the postcode sector level within the EELG model.

When developing the nine LCL household types and their associated demand profiles, Imperial College London further broke these profiles out by the five Elexon seasons (see Section 3.2 for further details). Since the EELG model is resolved to the
twelve months of the year (as well as providing a peak day forecast), it was necessary to further disaggregate the demand profiles of the nine LCL household types by month. Once this process was completed, the characteristic monthly demand profiles for each of the nine LCL household types were integrated into the EELG model and, combined with the distribution of the nine household types at postcode sector level, used to generate a set of demand profiles for households of each type within each postcode sector included in the model. The distribution of the nine LCL household types at postcode sector level was also combined with UK Power Network’s distribution network data within the EELG model, enabling the demand profile to be generated for each distribution substation on the basis of LCL consumer data.

The LCL trials also collected load profile data for electric vehicles and heat pumps which have been incorporated into the EELG model. However, since this report is focused specifically on energy efficiency impacts for existing appliance loads, the impact of future wider-scale adoption of electric vehicles and heat pumps was turned off in the model when producing the outputs for this report to isolate appliance energy efficiency impacts only. Load projections for electric vehicles and heat pumps are covered in LCL Reports B2 [Ref. 16] and B5 [ICL4] where it was found that EVs and HPs are expected to contribute approximately 89 MW to the LPN peak demand in the year 2020 (based on the UK Power Networks RIIO ED1 core uptake scenario), which represents 1.5% of LPN load peak demand in that year. The forecasts suggest that an additional primary substation and circa 31 secondary substations will require reinforcement due to EVs and HPs alone by 2020.

2.4.2.2 Energy efficiency considerations
In addition to a re-modelling of domestic consumer demand, the forecasts of appliance replacement rates have also been updated in the EELG model using the insights into appliance ownership (number and type of appliances for each of the nine household types) provided by the LCL appliance survey (see Section 3.3 for further details). Using these data, it was possible to evaluate the energy savings expected from the uptake of energy efficient appliances for each of the nine household types. For this aspect of the model, appliances were grouped into seven categories: lighting, cold, wet, cooking, TV and entertainment, information and communications technology and other appliances (see Section 3.3 for more details on the appliances within each category).

For each of the seven appliance categories, new uptake scenarios were developed, as shown in Figure 9. These new uptake trajectories are based on the latest data from the Energy Consumption in the United Kingdom (ECUK) dataset [Ref. 23] published by DECC in July 2013, current EU energy label data, European Commission policy guidelines and relevant components of the Market Transformation Program (MTP) dataset. Using this new approach, the improvements in energy efficiency are updated to the most recent data available and hence the projections shown in Figure 9 start from 2013. For some appliance categories there is a complex trade-off between changing appliance sizes and efficiency improvements (e.g. TV and entertainment and Information and Communication Technologies (ICT) appliances). Since the most significant contribution to loads within the “other” appliance category comes from water and space heating devices, the energy savings trajectories for this appliance category were conservatively based on the small improvements expected for conventional water and space heating appliances. Full details on the assumptions for each appliance category and scenario are provided in Appendix A. Similarly to the original modelling approach, there is a choice of “reference”, “future policies” and “best available technology” scenarios which have been updated with the latest policy and appliance data as covered in more detail in Appendix A:

- New “reference” scenario: A “business as usual” scenario that projects appliance energy efficiency savings based on the impact of all currently implemented policies, but not considering future policy impacts;
- New “Future policies scenario”: Considers all currently implemented policies as well as legislated policies that are formally signed-off and scheduled to come into effect on a specified future date (the specific future policies considered are listed in Appendix A); and
- New “Best Available Technology” (BAT) scenario: This is a hypothetical scenario of what would happen if only the best available technologies [Ref. 20] were taken up from now onwards.
Figure 9: Updated energy efficiency savings per appliance in the EELG model.

a) Wet appliances

b) Cold appliances

c) Lighting appliances
d) Cooking appliances

e) TV and entertainment appliances

f) ICT appliances
g) Other appliances in original EELG model

Energy savings

<table>
<thead>
<tr>
<th>Year</th>
<th>Original 'BAT' scenario</th>
<th>Original 'future policies' scenario</th>
<th>Original 'reference' scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2020</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>2030</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>2040</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>2050</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Energy savings per appliance

<table>
<thead>
<tr>
<th>Year</th>
<th>Other appliances in original EELG model</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>0%</td>
</tr>
<tr>
<td>2020</td>
<td>10%</td>
</tr>
<tr>
<td>2030</td>
<td>20%</td>
</tr>
<tr>
<td>2040</td>
<td>30%</td>
</tr>
<tr>
<td>2050</td>
<td>40%</td>
</tr>
</tbody>
</table>

Legend:
- Cyan: Original ‘BAT’ scenario
- Red: Original ‘future policies’ scenario
- Green: Original ‘reference’ scenario
When comparing the new appliance level energy savings forecasts (shown in Figure 9) to the original forecasts (shown in Figure 7), it can be seen that the “future policies” scenario is typically more conservative (relative to the best available technology scenario) in the updated forecasts. This is because the “future policies” scenario in the original forecasts considered anticipated policies and likely changes to existing policies, whereas the new “future policies” scenario now only considers legislated policies that are formally signed-off and scheduled to come into effect on a specified future date. This opens a wider gap between the efficiency savings that can reasonably be expected under the “future policies” scenario and the hypothetical best-case outcome of the “best available technology” scenario.

In addition to the uptake of more efficient appliances, the EELG model also considers future growth of the housing stock (related to population growth) and changing appliance ownership patterns per household. The increases in appliance stock per household (shown in Figure 10) are based on ECUK and MTP data.

**Figure 10: Appliance stock increase (per household) for all efficiency scenarios**

The current average electricity consumption (per appliance) for each appliance category was determined using the latest ECUK statistics published by DECC [Ref. 23]. By combining the average UK appliance consumption from ECUK with the efficient appliance uptake scenarios described above (which are based on ECUK, DECC and MTP data), the future savings effect on annual domestic consumption was derived. For each appliance category, a set of monthly-averaged demand profiles [Ref. 23] were extracted from DECC and Defra’s Household Electricity Usage Study (HEUS) – a detailed trial examining the electricity usage of individual appliances in 250 owner-occupier [Ref. 24] English homes between 2010 and 2011. By distributing the energy savings brought about by efficient appliance uptake across the HEUS appliance load profiles, it was possible to derive the load profile impact of efficient appliance uptake for each appliance category (see Figure 11). By combining this with appliance ownership data for different household types from LCL, it was possible to obtain a new level of demographically resolved energy efficiency forecasting in the EELG model.

Within the Low Carbon London project, Imperial College London also extended their bottom-up model of household demand based on the data from the appliance survey. The bottom-up model generates new demand profiles by simulating the actions of individuals in the house as they switch on lights, cook, boil the kettle and so on. This model is more suitable for examining the effects of lower numbers of customers and timescales shorter than half-hourly averages, and the potential for new household demand to impact voltage profiles on a feeder. More detail can be found in the Imperial College Report C2: The effect of energy efficient appliances on low voltage networks™ [ICLS].

**Figure 11: Example illustration of the impact of efficient appliances on the domestic load profile**

There is currently limited data available on the consumption and energy efficiency of individual appliances within households of different income and occupancy levels within Great Britain. Therefore, it was necessary to assume the savings made per appliance upgraded were the same across all household types and only the number and type of appliances being upgraded varied across each household type.
The energy efficiency analysis undertaken in this report makes use of the smart meter data and appliance ownership survey responses obtained from the LCL trials. The smart meter data was used to understand the electricity consumption of nine different household types and the appliance ownership information was used to determine the future energy efficiency savings achieved by each of these household types as they replace existing appliances with more efficient ones.

Given the importance of the LCL smart meter trial for the analysis covered in this report, this chapter provides a brief overview of how the participants in the LCL trial were selected, the results that were collected and how the datasets were used to establish electricity consumption patterns for nine household types. Further details on these aspects of the LCL project can be found in the following Imperial College Report C2: The effect of energy efficient appliances on low voltage networks” [ICL5], “A2: Residential consumer attitudes to time-varying pricing” [ICL1] and “A3: Residential consumer responsiveness to time-varying pricing” [ICL2].

3.1 Trial participants – smart meter trials and appliance survey

This section evaluates the demographic composition of the smart meter trial participants. Furthermore, the overlap between the monitored group of households and the Greater London population is investigated.

All households participating in the smart meter trial were recruited from the London Power Network (LPN) licence area of UK Power Networks and were all EDF Energy customers. British Gas smart meter customers were also recruited to provide data to LCL, however, their data was not used for the energy efficiency analyses as it was only the EDF Energy customers who were involved in the smart meter trial that were issued the appliance surveys. Compatible smart meters with pre-pay functionality were not available for the trial, and therefore households on a pre-paid tariff could not participate. Dual-fuel customers were not included in the trial to avoid potential confusion caused by introducing separate bills for dual-fuel clients. Economy 7 households were also excluded from the LCL trials since the Economy 7 tariff is a static Time of Use tariff. Households with any form of micro-generation were excluded because electricity generation would have distorted the demand measured by the smart meter. Figure 12 shows which households were monitored in the LCL smart meter trial.
It is recognised that the exclusion criteria described above introduces some sample bias into the results of the LCL trial. For example, households on Economy 7 tariffs typically exhibit higher levels of total consumption (e.g. from additional night storage primary electric space heating) than single rate tariff households [Ref. 25]. This is worth bearing in mind when interpreting the load profiles of the nine LCL household types in Section 3.2.

To ensure that the mix of households monitored in the LCL trial gave a good demographic representation of the Greater London population, the Acorn consumer classification [Ref. 21] of each monitored household was obtained. Acorn data is generated by CACI Limited, and it segments the UK population based on demographic data and social factors (see Table 6 for a list of the 17 Acorn household types). This demographic segmentation gave insight into the mix of households monitored in the trial and also enabled a detailed analysis of consumption patterns specific to various household types, as explored in Section 3.2.

The distribution of Acorn groups was monitored throughout the recruitment process. To ensure that the trial participants gave a good representation of the Greater London population, households were targeted for recruitment if they belonged to an Acorn group that was underpopulated. The resulting distribution of Acorn groups across the LCL trial participants is shown in Figure 13 (based on data analysis for LCL Report A3 [ICL2]).
3.2 Trial results – smart meters

One objective of the smart meter trial was to investigate the consumption characteristics of domestic demographic subgroups. To do this, the participating households were first grouped according to their Acorn demographic type (the 17 Acorn demographic types are listed below in Table 6). To reduce the number of demographic categories, and to further ensure that each sub-group contained a sufficiently large sample size, the 17 Acorn types were then aggregated into three broader categories: “affluent”, “comfortable” and “adverse” based on household income.

Table 6: The 17 Acorn 2010 household categories along with their demographic groupings

<table>
<thead>
<tr>
<th>LCL category name</th>
<th>Acorn category</th>
<th>Acorn type</th>
<th>Acorn type name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affluent</td>
<td>Wealthy Achievers</td>
<td>A</td>
<td>Wealthy Executives</td>
</tr>
<tr>
<td></td>
<td>Urban Prosperity</td>
<td>B</td>
<td>Affluent Greys</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>Flourishing Families</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>Prosperous Professionals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>Educated Urbanites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>Aspiring Singles</td>
</tr>
<tr>
<td>Comfortable</td>
<td>Comfortably Off</td>
<td>G</td>
<td>Starting Out</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>Secure Families</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I</td>
<td>Settled Suburbia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>J</td>
<td>Prudent Pensioners</td>
</tr>
<tr>
<td>Adversity</td>
<td>Moderate Means</td>
<td>K</td>
<td>Asian Communities</td>
</tr>
<tr>
<td></td>
<td>Hard-Pressed</td>
<td>L</td>
<td>Post-Industrial Families</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>Blue-collar Roots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>Struggling Families</td>
</tr>
<tr>
<td></td>
<td></td>
<td>O</td>
<td>Burdened Singles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P</td>
<td>High-Rise Hardship</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q</td>
<td>Inner City Adversity</td>
</tr>
</tbody>
</table>
Household size was then used as a second classification dimension with trial participants being divided into “one person”, “two person” and “three or more person” households. Combining the three demographic categories with the three occupancy groupings yielded a three-by-three matrix of nine household types as shown below in Table 7.

Table 8: The three-by-three matrix used to classify the nine household types used in LCL along with the sample size for each group (number of households who filled in the appliance survey)

<table>
<thead>
<tr>
<th>Household income</th>
<th>1</th>
<th>2</th>
<th>3+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affluent</td>
<td>406</td>
<td>404</td>
<td>226</td>
</tr>
<tr>
<td>Comfortable</td>
<td>244</td>
<td>312</td>
<td>213</td>
</tr>
<tr>
<td>Adverse</td>
<td>325</td>
<td>281</td>
<td>236</td>
</tr>
</tbody>
</table>

By combining the smart meter electricity consumption data of each household type, Imperial College London built average demand profiles for each of the nine household types described in Table 7. The demand profiles for the nine household types are shown in Figure 14 (based on data analysis for LCL Report A3 [ICL2]), for each of the five seasons as defined by Elexon [Ref. 26]. For each season in Figure 14, the relevant demand profile for Elexon’s Profile Class 1 is also shown. Profile Class 1 refers to the average demand profile for domestic unrestricted (i.e. not Economy 7) customers as used by Elexon.
Figure 14: Average demand profiles, broken down by the nine household types and Elexon season. All figures are based on the smart meter trial data recorded in the LCL project. [ICL1]
As can be seen in Figure 15 and Figure 16 (based on data analysis for LCL Report A3 [ICL2]), household occupancy is a strong driver for both total electricity consumption across the whole year (important from an energy supply and emissions reduction perspective) and also the peak demand (particularly important from the perspective of distribution network investment as well as energy generation capacity). Within each income classification, the “three or more person” households consume the most electricity annually and also have the highest evening peaks. Although the effect of household income is less pronounced, income also correlates well with annual consumption and peak load.

3.3 Trial results – appliance survey

The LCL appliance survey provides valuable insight into the number and type of appliances installed in the monitored households. Using these data, it is possible to compare the distribution of appliances across the nine household types. The following electrical appliance types were covered in the LCL appliance survey:

- **Lighting**: traditional incandescent lights, halogen lights (such as modern halogen spotlights), low energy lights (i.e. compact fluorescent lights), fluorescent tubes and Light-Emitting Diodes (LEDs);
- **Cold appliances**: fridges, freezers and fridge-freezers;
- **Wet appliances**: washing machines, tumble dryers, washer-dryers and dishwashers;
- **Cooking appliances**: electric hobs, electric ovens and microwaves;
- **TV and entertainment appliances**: Televisions (TVs), dvd/blu-ray players, cable TV boxes (e.g. Virgin), satellite TV boxes (e.g. Sky), Freeview TV boxes and games consoles;
- **Information and Communications Technology (ICT)**: desktop computers, laptop computers, printers and routers; and
- **Other**: electric showers, over-sink electric water heaters and portable electric heaters.

Imperial College London made a detailed analysis of the appliance ownership patterns across the nine LCL household types [Ref. 27]. For example, Figure 17 shows the confidence limits for several appliances from the household survey for the “affluent 1 person” household type where it can be seen that, with 95% confidence, between 60.1% and 69.6% of this household type had one electric oven.
Figure 17: An example of Imperial College London’s analysis of the LCL appliance ownership patterns showing several appliances for the “affluent 1 person” household type.

Figure 18: The average number of light bulbs for each household type.

The ownership patterns of cold appliances have very different characteristics. The total number of fridges and freezers for each household type are shown in Figure 19 below. It can be seen that there is only a slight increase in cold appliance ownership with household size and household income has a limited influence.

Figure 19: The average number of cold appliances for each household type.

Figure 18 shows the distribution of light bulbs for each household type. The total number of lights increases with household size, which is not surprising as larger dwellings are expected to have more lighting. However, “comfortable 3+” and “adverse 3+” household types reported fewer light bulbs than one might expect (compare with “comfortable 2” and “adverse 2”). A possible explanation for this is that larger households may have overlooked lights more easily. It is also worth noting that the share of efficient lights per household (LED, fluorescent tubes and low energy compact fluorescent lights) increases from “affluent” to “adverse” household types, indicating that “affluent” household types currently own the least efficient lighting.
Figure 20 shows that ownership of wet appliances increases with both household occupancy and income. While the number of washing machines is reasonably consistent across all household types, dishwashers and tumble-dryers are more prominent in high-occupancy households.

**Figure 20: The average number of wet appliances for each household type**

Cooking appliances ownership is relatively uniform across the different household occupancy levels and demonstrates only minor variation with household income. “Affluent” household types own slightly more electric cooking equipment than “comfortable” and “adverse” household types.

**Figure 21: The average number of cooking appliances for each household type**

Figure 22 and Figure 23 display the ownership patterns for TV and entertainment appliances and ICT appliances. For both categories, there is a strong correlation between appliance ownership and household size. Interestingly, while higher income households tend to own more ICT appliances, the ownership of TV and entertainment appliances is less dependent on income and actually shows some reverse correlation between income and the number of appliances owned.

**Figure 22: The average number of TV and entertainment appliances for each household type**

**Figure 23: The average number of ICT appliances for each household type**
4

Energy efficiency impacts on domestic household types

This chapter investigates the appliance energy savings potential of the nine LCL household types and explores how appliance energy savings will affect their load profiles. The methodology used for applying the smart meter and appliance ownership data from LCL to obtain the results reported in this chapter is covered in detail in Section 2.4.2. Using this approach, it was possible to break down the demand profiles of the LCL household types (shown in Section 3.2) into appliance categories as summarised in Figure 24. All scenarios referred to in this and the following chapters are the new scenarios developed for this report, which are described in Section 2.4.2.2.

4.1 Electricity demand of the LCL household types across different appliance categories

The contribution of each appliance category to household demand has been compared with that observed in DECC and Defra’s Household Electricity Usage Study (HEUS). As shown in Figure 24, the relative contribution of each appliance category to household demand correlates well between the LCL average and the HEUS findings. The “other” appliance category shown in Figure 24 includes space and water heating appliances as well as miscellaneous and unmonitored appliances.

It can also be seen in Figure 24 that the HEUS average annual household consumption (4,041 kWh) [Ref. 27] is somewhat higher than that observed for LCL (3,542 kWh). Comparison with the average household electricity demand from DECC’s National Energy Efficiency Data-Framework (4,100 kWh) [Ref. 28] reveals a similar outcome. In both cases, this discrepancy is likely related to the exclusion of Economy 7 households (which typically have higher electric space heating demands) from the LCL trial. Indeed, DECC reports that when Economy 7 meters are not considered, the average household annual consumption for Great Britain is 3,670 kWh which matches well with the LCL findings [Ref. 34]. For ease of comparison between the LCL trial and the HEUS findings, the HEUS data is also scaled down to the average household demand from the LCL trial in Figure 24.
4.2 Annual appliance energy efficiency savings for each of the LCL household types

By combining the LCL appliance ownership and demand profile data with the efficiency improvement trajectories for each appliance category (shown in Section 2.4.2.2), it was possible to determine the appliance energy efficiency savings profiles for each household type under various future scenarios. The resulting household level appliance energy efficiency savings profiles for each household type and scenario (see Section 2.4.2 for the assumptions behind each scenario) are shown in Appendix B (Figures 39 to 44).

Figure 25 and Figure 26 give an overview of the annual appliance energy efficiency savings, at household level, across the household types for the three efficiency uptake scenarios in 2020 and 2030 (more detailed results are included in Appendix B). It can be seen in these two figures that overall efficiency savings typically increase with household size and income which is linked to the concurrent increase in annual household demand observed for these two characteristics (as discussed in section 3.2). However, there are significant nuances within individual appliance categories across the different household types, primarily linked to variations in appliance ownership patterns between these groups and how these interact with the savings opportunities available for the given appliance category.
It can be seen in Figure 25 and Figure 26 that lighting and cold appliances typically offer the greatest energy efficiency savings in 2020 and 2030 for the three scenarios. This is linked to the considerable appliance level savings from efficient modern appliances in these two categories (see Figure 9) combined with the significant proportion of household demand arising from these appliances (see Figure 24). The increasing number of lights found in more “affluent” and higher occupancy homes, gives rise to a strong correlation in energy efficiency savings with these two metrics. For example, “affluent 3+” household types offer an annual lighting saving of 270 kWh by 2030 in the “BAT” scenario, which is almost twice as much as for “affluent 1” and “adverse 3+” households [Ref. 35]. The annual efficiency savings from cold appliances also show some correlation with household occupancy levels (affluence has little influence on savings in this case). Cold appliance savings for “affluent 3+” households are 352 kWh by 2030 in the “BAT” scenario compared to 272 kWh for “affluent 1” households.

The remaining appliance categories either offer limited appliance level savings or represent a relatively small fraction of household demand and hence offer limited opportunities in the household level savings shown in Figure 25 and Figure 26. It is worth noting that TV and entertainment appliances do make a significant contribution to overall savings in the “BAT” scenario even when trends towards increasing sizes of these appliances are taken into consideration. Interestingly, the small reverse correlation between income and appliance ownership unique to this category means that the efficiency savings typically increase slightly with household adversity as well as occupancy levels.

The considerable increase in appliance efficiency savings under the “BAT” scenario relative to the other two scenarios illustrates the available energy efficiency potential that is left untapped by currently implemented policies (“reference” scenario) and legislated policies that are scheduled to come into effect on a specified future date (“future policies” scenario). This finding highlights the potential available for policy makers to achieve considerably higher levels of demand reduction through the use of more ambitious appliance energy efficiency policies.
4.3 Appliance energy efficiency savings for each of the LCL household types during the evening peak period

To provide an indication of household level appliance energy efficiency impacts on peak demand, the energy saving potential of each appliance category was evaluated during the evening peak period (17:00 – 22:30). This involved an analysis of the load profiles of energy efficiency savings in Appendix B to produce Figures 27 and 28 [Ref. 31].

The concentration of demand from lighting, cooking and TV and entertainment appliances during the evening peak means their contribution to peak savings is increased relative to the annual savings potentials discussed above. So while lighting and cold appliances also dominate the energy efficiency savings during the evening peak period, the relative importance of lighting is significantly increased for this reason. The relative contribution of TV and entertainment appliances is also increased, particularly for the “BAT” scenario.

Again, owing to the increasing number of lighting devices among more affluent and higher occupancy households, the energy efficiency savings from lighting during the evening peak are considerably larger in these cases. Similarly, the peak savings from cold and TV and entertainment appliances both increase significantly with household occupancy levels.

As was observed in the previous section, the considerable increase in savings observed for the “BAT” scenario highlights the significant opportunity for policy makers to achieve large peak demand reductions through the implementation of more ambitious appliance energy efficiency policies.

Figure 27: The average change in electricity demand during the evening peak (17:00 – 22:30) at household level for each household type in 2020
4.4 Comparison of appliance energy efficiency savings with those identified in the HEUS study

Further analysis of the HEUS data obtained by DECC and Defra revealed the appliance energy efficiency potential for various household types [Ref. 32]. This section of the report provides a comparison between the appliance energy efficiency potentials identified in the HEUS analysis [Ref. 33] with the appliance energy efficiency savings observed above for the nine LCL household types. In the HEUS analysis, the household technical potentials for appliance efficiency saving were calculated based on the following energy efficiency improvements [Ref. 34]:

- Replacing all cold appliances with class A+ or A++ equipment;
- Replacing all incandescent and halogen light bulbs with compact fluorescent lights;
- Reducing all standby power for the audiovisual and computer sites;
- Replacing existing washing machines, clothes dryers and dishwashers with energy efficient alternatives; and
- Replacing desktop computers with laptops.

Figure 29 shows the appliance energy efficiency savings potentials for the various Experian household types (referred to as Experian Mosaic Groups [Ref. 13]). It should be noted that the names for each of the Mosaic Groups are as defined by Experian and do not reflect the naming conventions used within the LCL project.

It can be seen in Figure 29 that the HEUS appliance energy efficiency savings potentials are not strongly correlated with household income levels. This may be due to the small sample size in this study (250 households, which meant that some Mosaic Groups in Figure 29 contained as few as 4 households), or the different approach used in the HEUS analysis to calculate efficiency savings potentials based on the current consumption of each individual appliance within the household. This highlights the value of better understanding the appliance efficiency ratings and energy consumption levels of existing domestic appliances within different household types across Great Britain. It is recommended, where possible, that future appliance trials obtain data on the efficiency ratings and/or consumption from existing devices within the monitored households to expand the data available in this area.
The appliance efficiency savings potentials reported for the HEUS analysis are technical potentials. That is, they represent the total savings that could be achieved if all the appliance efficiency improvements listed above were implemented immediately. As such, the HEUS analysis does not provide a projected rate of uptake for energy efficiency savings to be implemented. However, they can be compared to the appliance efficiency scenarios discussed above given sufficiently long timescales (i.e. 2030) by which time all appliances will have been replaced.

The HEUS estimates of appliance efficiency savings potential align somewhere between the “future policies” and “best available technology” scenario projections of this report for 2030 (see Figure 30). While some of the energy efficiency assumptions within the HEUS analysis align with those of the “best available technologies” scenario in this report, the HEUS analysis does not consider appliance stock increases per household or savings from “cooking” and “other” appliances. Furthermore, this study considers efficiency savings from a broader range of appliances within the lighting, ICT and TV and entertainment categories relative to the HEUS analysis. These differences account for the higher appliance efficiency savings under the “best available technology” scenario in this report relative to that of the HEUS analysis.

Figure 30: A comparison of the LCL appliance efficiency savings with the efficiency potentials identified in the HEUS findings
In this chapter, the appliance energy efficiency savings for different household types, explored in chapter 5, are scaled up to evaluate the implications for different geographical regions within Great Britain. The distributions of the nine LCL household types across Great Britain, England, Scotland, Wales and Greater London were used to determine the total appliance energy efficiency savings expected in these geographical regions under the three future scenarios introduced in Section 2.4.2.2. The contribution of each of the nine LCL household types to the total savings in each of these regions is also reported.

The distribution of each of the nine LCL household types for Great Britain, England, Scotland, Wales and Greater London was determined using Acorn household type and occupancy data provided by CACI [Ref. 35]. These data were combined with Office for National Statistics (ONS) [Ref. 36] and Greater London Authority (GLA) [Ref. 37] projections of the number of households within each of these regions to determine the future number of each LCL household type within each area.

5.1 Comparison of the energy efficiency impacts for different regions within Great Britain

This section of the report explores how the energy efficient appliance savings vary across different regions within Great Britain. Figure 31 gives an overview of the distribution of household types for England, Scotland, Wales and Greater London compared to that of Great Britain. The most noticeable regional deviation from the Great Britain average distribution of household types occurs for Greater London which has a significantly higher proportion of “affluent” households and a lower fraction of “comfortable” households, highlighting the known income disparity in London relative to the rest of Great Britain.
Figure 31: The distribution of household types for various Great Britain geographic regions

The distribution of household types along with their corresponding appliance ownership patterns, electricity consumption and appliance savings (introduced in chapters 3 and 4) were used to generate average load profiles and appliance efficiency savings for each region under various scenarios (as shown in Appendix C). Figure 32 and Figure 33 summarise the appliance energy savings impacts of the five regions for the “future policies” scenario in the years 2020 and 2030.

Figure 32 and Figure 33 show that, as observed in chapter 4, cold and lighting appliances contribute significantly towards the total annual appliance energy savings potential for all regions. When examining the peak demand savings from appliance energy efficiency across these regions (as shown in Figure 34 and Figure 35), the relative contribution from lighting appliances is increased due to the concentration of lighting demand during the evening peak period (as discussed in chapter 4). Given the similarities in household type distributions for England, Scotland, Wales and Great Britain as a whole, the distribution of appliance efficiency savings in each of these cases are comparable. Of course, the different number of households contained in each of these regions gives rise to different total appliance energy efficiency savings and peak demand reductions as summarised in Table 8 and Table 9, respectively.

For Greater London, the increased share of “affluent” household types combined with the large energy efficiency savings offered by these households, means that they account for about 58% of the total annual appliance efficiency savings by 2020 under the “future policies” scenario. Moreover, almost half of this “affluent” savings opportunity is from the larger “affluent 3+” households. Though less marked, large savings from “affluent” households can also be observed for the other regions shown in Figure 32 and Figure 33 (e.g. “affluent” households account for 41% of annual appliance efficiency savings in 2020 for Great Britain under the “future policies” scenario). Similarly, “affluent” households accounted for 57% of evening peak demand reductions from appliance energy efficiency (again, almost half of this was from “affluent 3+” households).

These findings have important implications for DNOs when considering where energy efficiency impacts could be concentrated within their networks. Network assets feeding domestic regions with high concentrations of “affluent” and high occupancy households may experience significantly higher levels of appliance energy efficiency savings.

To put these findings in context, the total annual appliance efficiency savings reported for Great Britain in 2020 under the “future policies” scenario (see Table 8) equate to approximately 8% of the projected domestic demand for Great Britain in 2020 (122 TWh [Ref. 38]). This saving increases to approximately 19% of annual domestic demand within Great Britain in 2020 under the “best available technology” scenario, illustrating that appliance efficiency savings have the technical capacity to be more than doubled with appropriate additional policy interventions.
Figure 32: Change in annual consumption for various regions in GB in the 2020 “future policies” scenario
Figure 33: Change in annual consumption for various regions in GB in the 2030 “future policies” scenario

- a) Great Britain
- b) England
- c) Scotland
- d) Wales
- e) Greater London

Savings from energy efficiency, GWh

- Other
- Cooking
- Cold
- Wet
- ICT
- Lighting
- TV and entertainment
Figure 34: Change in demand during the peak period for various regions in GB in the 2020 “future policies” scenario
Figure 35: Change in demand during the peak period for various regions in GB in the 2030 "future policies" scenario.

- **a) Great Britain**
- **b) England**
- **c) Scotland**
- **d) Wales**
- **e) Greater London**

Legend:
- Other
- Cooking
- Cold
- Wet
- ICT
- Lighting
- TV and entertainment
### Table 8: The total annual appliance energy efficiency savings for each region

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<th>2030</th>
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<td>Future policies</td>
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### Table 9: The average peak demand reduction from appliance energy efficiency for each region

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<th>2030</th>
</tr>
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<td>Future policies</td>
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<tr>
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<td>Wales</td>
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<td>80</td>
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<tr>
<td>Greater London</td>
<td>170</td>
<td>210</td>
</tr>
</tbody>
</table>
5.2 Comparison of appliance energy efficiency savings with those identified in the HEUS study

As in chapter 4, the appliance energy efficiency savings across Great Britain are compared to those found in the HEUS analysis [Ref. 32], which addresses the appliance energy savings potential for different household types (based on Experian Mosaic Group [Ref. 13] consumer types). The distribution of Experian Mosaic Groups within the UK was scaled by the forecast number of households within Great Britain [Ref. 36] for 2020 and 2030 to obtain the HEUS appliance efficiency savings potentials shown in Figure 36.

As observed in chapter 4, the HEUS estimate of appliance efficiency potential for Great Britain falls somewhere between the “future policies” and “best available technology” scenarios of this report in 2030. The “best available technology” scenario in this report forecasts significantly higher appliance energy efficiency savings for Great Britain than the scaled HEUS results primarily due to the fact that the HEUS results do not include the impact of appliance stock increases, savings from “cooking” and “other” appliances or as broad a range of appliances within the lighting, ICT and TV and entertainment categories as this report.

It is worth noting that the efficiency savings contribution of “affluent” households in the present study is higher than that reported by the HEUS analysis. This may be because the annual consumption of “affluent” households (and hence their efficiency savings opportunity) was found to be higher (relative to the average household) in the LCL smart meter trials than that reported by the HEUS analysis. Also, as discussed in chapter 4, the small sample size in the HEUS analysis (250 households) contributes to uncertainty when disaggregating energy efficiency savings by household type.

Figure 36: Appliance efficiency savings for Great Britain compared to the HEUS findings scaled to this level, forecasted 2030
The impacts of energy efficiency versus Time of Use tariffs

This chapter compares the effect of appliance energy efficiency improvements on domestic demand (particularly during the evening peak period) with the impacts observed for the LCL dynamic Time of Use (dToU) tariff trial and four other UK static Time of Use (sToU) tariff trials. In addition to demand reductions during high price periods, the majority of UK ToU trials also observe a reduction in total demand (i.e. demand is also reduced outside the high price periods). This is thought to be caused by increased awareness of energy consumption behaviours and curtailment of some activities by trial participants. Both of these energy reduction aspects are explored in this chapter relative to the energy efficiency savings reported above.

7.1 LCL dynamic Time of Use trial setup and results

The LCL project conducted a dynamic Time of Use tariff trial, which exposed trial participants to electricity price changes with 24 hours’ notice. The electricity price of the dToU tariff was set dynamically, according to a schedule designed to influence consumption during so-called “supply following” (or wind twinning) and “constraint management” events. For the purpose of this report, only “constraint management” events were examined since they incentivise households to reduce consumption specifically during the hours of peak demand on the network. “Supply following” price events simulated the availability of intermittent renewable electricity sources and, as such, were not specifically related to periods of high demand [Ref. 39].

For the “constraint management” events of the LCL dToU trial, the peak time was defined as a 5.5 hour interval, starting at 16:30 or 17:30 and a high price was applied during this time and a low price for the rest of the day [Ref. 40]. The consumer response to the dToU tariff is analysed extensively Report A3: “Residential consumer responsiveness to time-varying pricing” [ICL2]. Considering only “constraint management” events, it was found that the trial participants reduced overall consumption by an average of 6.4% and consumption during peak times by an average of 8.0%.
In order to interpret the results of the dToU trial, it is worth noting that there were several interventions encouraging the participants to adapt their consumption. The electricity price during high price events was almost 16 times higher than during low price events. This was a very high price differential in comparison to the UK sToU trials (see Figure 35). Trial participants were notified about price changes at 8:30am on the day before a price event. Notifications were delivered via in-home displays and mobile phone text messages. In addition, a monthly feedback letter was sent that gave insight into the historic consumption (kWh) and total cost, as well as a breakdown of how much electricity was consumed in which price bracket. As in the case of the sToU trials, the dToU tariff structure was designed to be cost neutral (i.e. if consumers did not change their behaviour, their total bill over the trial period would remain the same). Additionally, if any bill increases did occur due to varying prices these were reimbursed to the trial participants.

6.2 Overview of static Time of Use trials

The four UK sToU trials examined in this report are:

- Energy Demand Research Project: SSE Trials [Ref. 41] (abbreviated to SSE);
- Energy Demand Research Project: EDF Energy Trials [Ref. 41] (abbreviated to EDF Energy);
- Customer-Led Network Revolution [Ref. 42] (abbreviated to CLNR); and
- Northern Ireland Keypad Meters [Ref. 43] (abbreviated to NIK).

**EDF Energy and SSE trials**

The Energy Demand Research Project (EDRP) was a large study into consumers’ responses to various interventions, ranging from the provision of information about energy usage to sToU tariffs. As part of the EDRP, EDF Energy and Scottish and Southern Energy (SSE) conducted separate sToU trials. The EDF Energy trial had a control group (135 households), a group with a real-time-displays (141 households) and a group with both a real-time-display and a sToU tariff (170 households) and lasted for two years. The SSE trial tested numerous interventions (energy advice booklets, monthly bills with detailed consumption data (paper/online), real-time displays of consumption and a financial incentive to reduce total consumption), which were all tested with and without a sToU tariff on different households. In total, the SSE trials involved 3,354 households, 58% of which were exposed to a sToU tariff. For the purpose of this report, the results from the SSE trials are not addressed individually; only the trial results of the most effective peak-shifting interventions (i.e. sToU tariff combined with an advice booklet and monthly bills with graphs) are discussed (for a more detailed discussion of the other SSE trial interventions please refer to reports by Element Energy [Ref. 32] and AECOM [Ref. 41]).

**Customer-led network revolution trial (CLNR)**

The Customer-Led Network Revolution is a large project funded by Ofgem’s Low Carbon Networks Fund. The results shown here are for 112 participating households that were monitored both before (April to November 2011) and after (April to November 2012) the introduction of the sToU tariff. As part of this project, the participating households were equipped with smart meters, real-time displays and provided with energy advice booklets.

**Northern Ireland keypad meter study (NIK)**

In the Northern Ireland Keypad Meter study, 100 households on prepaid meters participated in a sToU trial. The consumption data of the trial participants was compared to a control group of 100 households. Since this trial involved the use of prepaid meters (with a real-time display) there is a possible demographic bias in this study. In 2009, it was estimated that around 30% of domestic electricity meters in Northern Ireland were keypads, and a substantial proportion of the keypad consumers were classified as “low-income” [Ref. 44]. For comparison, 3.8 million UK consumers relied on pre-payment meters in the same year, representing approximately 15% of all households.

Figure 37 provides an overview of the tariff price structure for the four UK sToU trials.
6.3 Comparison of demand reduction from appliance energy efficiency versus Time of Use trials

To compare the effects of ToU tariffs and appliance energy efficiency savings, the following two metrics are used (both of which are introduced in chapter 4):

- “Change in annual consumption”, which compares the total annual demand before and after the impact of efficient appliance uptake or the ToU tariff; and

- “Change in peak demand”, which is a measure of the reduction in demand during a specific peak time [Ref. 45].

Figure 36 compares the appliance energy efficiency impacts from chapter 5 with those of the ToU trials described above. The energy efficiency impacts shown in Figure 36 are based on the savings for an average household in Great Britain. It should be noted that the variations in the design of the various trials being compared (such as sample size, the number of interventions, the type of complementary measures and the timing of the high-price signals, as described in Sections 6.1 and 6.2) mean that the comparisons made in Figure 36 are only intended to provide an approximate indication of the relative impacts from appliance energy efficiency and ToU tariff trials in the UK to date. As such, these comparisons should not be viewed as an unequivocal assessment of the relative performance of appliance energy efficiency versus ToU tariffs.

ToU trial participants were observed to typically reduce their total annual consumption (with the exception of the NIK trial, which may be related to the demographic bias in this trial). The level of total consumption reduction between the sToU (between a reduction of 12% and an increase of 2%) and dToU (6% reduction) trials were comparable. The considerable variation observed for the sToU trials is likely due to the different accompanying intervention measures and tariff conditions between these trials.

Figure 36 shows that the total appliance energy efficiency savings estimated for 2020 by the “reference” (8% reduction) and “future policies” (9% reduction) scenarios are comparable to those of the sToU and dToU savings. Interestingly, the “best available technology” scenario shows that there is still capacity for further domestic consumption savings if high efficiency appliances are more widely implemented (reaching a total saving of as much as 22% by 2020).
As intended, all ToU tariffs trials were observed to reduce domestic demand during high price periods (see Figure 38). The average peak reductions achieved by the sToU trials (between 10% and 13% reductions) were higher than those observed for the dToU (8% reduction). This may be linked to the regularity of the sToU price changes which allows consumers to establish regular high price avoidance strategies (e.g. timer-based solutions) that are not always possible under dToU conditions.

The peak demand reduction from appliance energy efficiency savings predicted by the “reference” (7%) and “future policies” (9%) scenarios in 2020 are also comparable with those of the ToU trials. Under the “future policies” scenario, a 9% reduction in peak demand is expected by 2020 due to appliance energy efficiency improvements, which could be extended to as much as 22% if more aggressive energy efficiency strategies are pursued. The implication is that further policies supporting the uptake of energy efficient appliances could significantly assist the management of peak network loads.

This is an important finding which illustrates the important role of appliance energy efficiency in reducing total domestic demand and peak demands within Great Britain. Furthermore, the additional capacity identified under the “best available technology” scenario reveals additional opportunities for policy makers to achieve greater domestic consumption reductions. In context, example costs for an average Greater London household to upgrade to more efficient appliances in line with the “best available technology” scenario could be of the order of £3,000 [Ref. 46]. There remains a question on the extent to which the DNOs are able to facilitate domestic energy efficiency, given that the typical annual charge for a DNO customer for the delivery of all services, not just local network reinforcement, is a fraction of these costs.

**Figure 38: The change in total annual consumption and peak demand for various ToU trials and energy efficient appliance uptake scenarios**
Conclusions

- The energy savings opportunities arising from the ongoing replacement of household appliances with modern equivalents have been assessed in this report for various future scenarios. The analysis made use of the smart meter and appliance ownership data collected in the LCL project along with the latest data on appliance sales trends, efficiency performance and applicable legislation;

- The potential savings (both in terms of total annual consumption and peak demand) from appliance energy efficiency improvements were found to increase with both household size and income levels in line with the generally higher demand observed for these households. When the household level findings were scaled up across different regions within Great Britain, it was found that the different mix of household types within each area had a significant impact on the domestic appliance efficiency savings in each case. Indeed, the particularly high proportion of “affluent” households in Greater London, combined with the large energy efficiency savings offered by these households, means that they account for about 57% of the peak demand reduction from appliance efficiency improvements by 2020 under the “future policies” scenario in this region. Moreover, almost half of the “affluent” household peak demand reduction in Greater London was from the larger “affluent” households with three or more occupants;

- Lighting and cold appliances were found to offer the greatest identifiable potential for energy efficiency savings to 2020 and 2030 for the three appliance replacement scenarios examined (“reference”, “future policies” and “best available technology”). This finding is linked to the considerable appliance level savings from efficient modern appliances in these two categories combined with the significant proportion of household demand arising from these appliances;

- Since electricity demand from lighting, cooking and TV and entertainment appliances tends to increase during the evening peak period, the contribution of these devices to peak savings from appliance energy efficiency is considerably increased. For this reason, the importance of lighting appliances for efficiency savings during the evening peak period is even more emphasised;
When considering all legislated energy efficiency policies that are currently implemented or scheduled for future implementation (i.e. the “future policies” scenario), significant annual appliance energy efficiency savings by 2020 may be possible for Great Britain (10.0 TWh), England (8.6 TWh), Scotland (0.9 TWh), Wales (0.5 TWh) and Greater London (1.3 TWh). In the best case scenario, where customers replace their appliances with the best available technologies over this period, the savings for Great Britain (23.1 TWh), England (19.9 TWh), Scotland (2.1 TWh), Wales (1.2 TWh) and Greater London (3.0 TWh) would be considerably larger, illustrating the further potential for savings that could be achieved using additional policy interventions. To put this in context, the savings by 2020 for Great Britain under the “future policies” scenario equate to approximately 8% of the projected domestic demand for Great Britain in 2020. Under the “best available technology” scenario, this saving is predicted to increase to approximately 19% of annual domestic demand for Great Britain in 2020. Of course, the ability to achieve these potential savings is dependent on consumer response to each of the policy initiatives as well as future appliance purchasing trends (e.g. relating to the size and number of appliances owned and used by each household);

The potential peak demand reductions from appliance energy efficiency savings (as high as 9% under the “future policies” scenario by 2020) were found to be comparable with those observed in the LCL dynamic Time of Use (dToU) trial (8%) and four UK static Time of Use (sToU) trials (between 10% and 13%). Importantly, this report reveals that new appliance efficiency interventions by policy makers could realise significant additional peak demand savings (reaching a peak reduction as high as 22% by 2020 under the “best available technology” scenario); and

The reduction in total consumption (i.e. over the entire day) from appliance energy efficiency savings (9% by 2020 under the “future policies” scenario) is also comparable with that observed for the sToU trial (6%) and dToU trials (between -2% and -12%). Again, considerable capacity exists to further reduce total domestic consumption (and hence greenhouse gas emissions) within Great Britain to as much as 22% in the “best available technology” scenario offering policy makers considerable scope to further utilise appliance energy efficiency as part of an ongoing emissions reduction and network management strategy.
Recommendations

8.1 Current DNO load forecasting

- The comprehensive load profile and appliance ownership datasets produced by the LCL smart meter trials enable DNOs to characterise existing domestic demand at a higher level of resolution than currently used by many DNO load forecasting tools. It is recommended that the load and efficiency savings profiles (see chapter 3 and 4) produced by LCL for various household types are used to investigate the practicality of developing regionally specific energy efficiency scenarios.

8.2 Understanding consumer response to energy efficiency initiatives

- The potential benefits from appliance energy efficiency are predicated on the customers responding as predicted to the policy initiatives. Further work is required to understand the mechanisms for encouraging the adoption of efficient appliances, along with the resulting costs and benefits of efficiency measures relative to other network reinforcement deferral strategies;

- The large unaddressed domestic energy efficiency opportunity observed between the current “future policies” trajectory and the maximum potential of the “best available technology” scenario represents a significant opportunity for policy makers to realise additional emission reduction savings and concurrent network benefits for various industry stakeholders. Further work is required to investigate how this large available savings potential could be most cost effectively realised; and

- Understanding the above two areas in greater detail will not only support policy makers in optimising appliance efficiency legislation, but will also offer DNOs and other industry stakeholders important insights into how domestic loads are likely to change on their networks in coming years as a result of energy efficiency improvements.

8.3 Future studies

- Where possible, future appliance trials and appliance surveys should obtain data on the efficiency of the existing devices within each household examined. This data would provide increased insight into the variation of efficiencies across the existing appliances owned by different household types. Using this information, it would also be possible to more accurately forecast the efficiency savings that could be achieved by different household types when upgrading to modern energy efficient appliances;
• It is also recommended that the range of appliances covered by future trials and appliance surveys be expanded. At present, there is a large “other” or “unknown” category in appliance ownership data within Great Britain, on which there is currently very little available data. With this additional data, it would be possible to more accurately assess the energy efficiency potential within this large, relatively unknown, area; and

• Given the considerably larger demand and energy efficiency opportunities among higher occupancy (3+) households, further studies exploring domestic appliance usage behaviours, energy efficiency and responsiveness to interventions should ensure that this group is appropriately targeted within the monitored households.
### Appendix A

**Table 10: Energy efficiency savings assumptions for each appliance category and scenario**

<table>
<thead>
<tr>
<th>Appliance category</th>
<th>Scenario</th>
<th>Common sources and assumptions for all scenarios</th>
<th>Scenario specific assumptions and policy considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wet appliances</strong></td>
<td>Reference</td>
<td>— Lifespan: MTP (e.g. 13 years for dishwashers)</td>
<td>Forecast of sales by energy rating under business-as-usual</td>
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<td>Future policies</td>
<td>— Breakdowns of sales and stocks by energy rating: ECUK 2013</td>
<td>Energy-related Products (ErP):</td>
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<td></td>
<td>BAT</td>
<td>— Average annual consumption by energy rating: derived from EU energy label definitions</td>
<td>— Washing machines: No 1015/2010</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>— Dishwashers: No 1016/2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Only best available technologies are purchased: A+++ washing machines, A tumble driers, and A+ dishwashers</td>
</tr>
<tr>
<td><strong>Cold appliances</strong></td>
<td>Reference</td>
<td>— Lifespan: MTP (e.g. 15 years for fridge-freezers)</td>
<td>Forecast of sales by energy rating under business-as-usual</td>
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<td></td>
<td>Future policies</td>
<td>— Breakdowns of sales and stocks by energy rating: ECUK 2013</td>
<td>Energy-related Products (ErP): No 643/2009</td>
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<tr>
<td></td>
<td>BAT</td>
<td>— Average annual consumption by energy rating: derived from EU energy label definitions</td>
<td>Only best available technologies are purchased: A++ energy rating</td>
</tr>
</tbody>
</table>

Appendices

Appendices  | 53
<table>
<thead>
<tr>
<th>Appliance category</th>
<th>Scenario</th>
<th>Common sources and assumptions for all scenarios</th>
<th>Scenario specific assumptions and policy considerations</th>
</tr>
</thead>
</table>
| **Lighting appliances** | Reference | — Breakdown of energy consumptions and stocks by lamp type: ECUK 2013  
— Replacement rates and energy savings achieved by replacement of technologies: derived from European Commission memo 09/368 (01/09/2009) | — Standard light bulbs are replaced with energy saving light bulbs  
— Standard halogens are replaced with halogens class C, and a small fraction (based on ECUK historic stock data) is replaced with LEDs  
— Standard light bulbs are replaced with energy saving light bulbs  
— Standard halogens are replaced with halogens class C until 2017 and then with halogen class B (Energy-related Products: No 244/2009 and 859/2009), and a small fraction (based on ECUK historic stock data) is replaced with LEDs  
— Standard light bulbs are replaced with CFLs and halogens with LEDs  
— Fluorescent Strip Lighting are replaced with first in class LEDs from 2020: MTP performance projections for LEDs |
| Future policies | | | |
| BAT | | | |
| **Cooking appliances** | Reference | — Breakdown of energy consumptions and stocks cooking appliance: ECUK 2013  
— Lifespan: derived from MTP for ovens and hobs (18 years), 8 years for microwaves, 9 years for kettles | Energy consumption of new appliances follows a projection based on the current trend for annual consumption of new appliances, from ECUK 2013  
Energy-related Products (ErP): No 66/2014  
Only best available technologies are purchased (e.g. eco-kettles, A rated electric ovens) |
| Future policies | | | |
| BAT | | | |
| **TV and entertainment appliances** | Reference | | Energy-related Products (ErP): No 642/2009 and 801/2013 |
| Future policies | | | |
| BAT | | | |
| **ICT appliances** | Reference | | Energy-related Products (ErP): No 617/2013 |
| Future policies | | | |
| BAT | | | |
| **Other appliances** | Reference | Saving effects of the “other” appliances are taken from MTP projections for water and space heating devices since these are the most significant contributors to loads within this category. | |
Appendix B

Figure 39: Annual average load profiles and efficiency savings for 2020, “reference” scenario

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cold appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
Figure 40: Annual average load profiles and efficiency savings for 2020, “future policies” scenario

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cold appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
Figure 41: Annual average load profiles and efficiency savings for 2020, “BAT” scenario

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cold appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
Figure 42: Annual average load profiles and efficiency savings for 2030, “reference” scenario

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cold appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
Figure 43: Annual average load profiles and efficiency savings for 2030, “future policies” scenario

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
Figure 44: Annual average load profiles and efficiency savings for 2030, “BAT” scenario

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cold appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
Appendix C

An overview of the appliance energy savings potential on the annual load profiles for various geographic regions is provided. For each region, the growth of the total number of households is projected for the years 2020 and 2030 (based on ONS and GLA forecasts). All charts display the load in kW for an average day.

**Figure 45: Annual average load profiles and efficiency savings for GB**

- **Efficiency savings due to wet appliances**
- **Efficiency savings due to Lighting appliances**
- **Efficiency savings due to TV and entertainment appliances**
- **Efficiency savings due to other appliances**
- **Efficiency savings due to cold appliances**
- **Efficiency savings due to cooking appliances**
- **Efficiency savings due to ICT appliances**
- **Residual demand**
Figure 46: Annual average load profiles and efficiency savings for England

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cold appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
Figure 47: Annual average load profiles and efficiency savings for Scotland

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cold appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
Figure 48: Annual average load profiles and efficiency savings for Wales

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cold appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
Figure 49: Annual average load profiles and efficiency savings for Greater London

- Efficiency savings due to wet appliances
- Efficiency savings due to Lighting appliances
- Efficiency savings due to TV and entertainment appliances
- Efficiency savings due to other appliances
- Efficiency savings due to cold appliances
- Efficiency savings due to cooking appliances
- Efficiency savings due to ICT appliances
- Residual demand
References

3. Imperial College Low Carbon London Learning Lab, 2014. The model was developed by a consortium led by EA Technology and including Element Energy, Gl. Noble Denton, Frontier Economics and Chiltern Power.
4. Developed in earlier work for the Committee on Climate Change, the Energy Technologies and the Department for Transport.
7. A U-value is a measure of heat loss in a building element such as a wall, floor or roof.


17. Car parc refers to the number of cars and other vehicles in a given region.


20. BAT is defined as the most efficient or lowest energy consuming technology.


22. Since household income was the underlying demographic classification criterion used for the nine LCL household types, the average income banding of the Acorn household types was compared to the average Experian Mosaic income bands to map the Acorn household types to the Experian Mosaic groups. Acorn and Experian are large information services companies that aggregate data (from sources such as the national census, local public records, property/realty records, the electoral role, credit records, etc.) to classify UK consumers and households into distinct household types based on details of the occupant demographics, lifestyle and consumer behaviour.

23. The ECUK dataset gives detailed data on appliance sales, stocks, and energy ratings. DECC publications on “Energy consumption in the UK” are available from: https://www.gov.uk/government/collections/energy-consumption-in-the-uk


25. DECC reports that across Great Britain, households with “ordinary” domestic meters (i.e. non-Economy 7) have an average annual consumption of 3670 kWh compared to 5628 kWh for households with Economy 7 meters in S. Khan and S. Stadnyk, “Sub-national electricity consumption statistics: Regional and local authority level statistics (2012 data)”, DECC, 2013.

26. Elexon defines five seasons for balancing and settlement profiles. These are defined as:

   - Winter: the period from the day of clock change from British Summer Time (BST) to Greenwich
   - Mean Time (GMT) in October, up to and including the day preceding the clock change from GMT to BST in March.
   - Spring: the period from the day of clock change from GMT to BST in March, up to and including the Friday preceding the start of the Summer period.
   - Summer: the ten-week period, preceding High Summer, starting on the sixteenth Saturday before the August Bank Holiday.
High Summer: the period of six weeks and two days from the sixth Saturday before August Bank Holiday up to and including the Sunday following the August Bank Holiday.

Autumn: the period from the Monday following the August Bank Holiday, up to and including the day preceding the clock change from BST to GMT in October.


28. DECC’s National Energy Efficiency Data-Framework (NEED) contains data about household gas and electricity consumption from energy suppliers, the Homes Energy Efficiency Database (HEED) and household demographic characteristics from Experian and other sources. This database characterises energy consumption for a range of variables such as region, property type, property age, number of bedrooms, income, number of adults, etc. In line with the LCL project, it shows greater electricity consumption with increasing household income and occupancy levels.

29. DECC reports that across Great Britain, households with “ordinary” (i.e. non-Economy 7) domestic meters (82% of households) have an average annual consumption of 3670 kWh compared to 5628 kWh for households with Economy 7 meters (18% of households) in S. Khan and S. Stadnyk, “Sub-national electricity consumption statistics: Regional and local authority level statistics (2012 data)”, DECC, 2013.

30. The savings from lighting appliances by 2030 in the “BAT” scenario were 148 kWh for the “affluent 1” household type and 142 kWh for the “adverse 3+” household type.

31. The peak demand reduction from energy efficiency shown in Figures 24 and 25 is the average reduction in peak demand between 17:00 – 22:30 for each appliance category in the annual demand profiles of the nine LCL household types. Limitations in the HEUS sample size for individual days and months meant that it was more accurate to consider the appliance efficiency impacts on the annual average profiles in this case.


33. Though the households monitored in the HEUS analysis were all owner-occupier homes, comprehensive demographic profiling during selection of the trial participants was used to ensure a nationally representative mix of social grades, occupancy levels, etc. As such, the HEUS households provide a suitable distribution of household incomes and occupancy levels for comparison to this project. For more details see: DECC, Defra and EST, “Household Electricity Survey: A study of domestic electrical product usage”, 2012.


35. The distribution of Acorn household types across each of the five regions was used to determine the distribution of household affluence in each case. Acorn occupancy data was only available for the whole UK, so this metric was assumed to apply to each of the five regions examined in this report. Acorn household type and occupancy data was obtained from: CACI, “Acorn Knowledge Database”, 2010.


38. The total domestic consumption in GB was reported by DECC to be 110 TWh in 2012 (40% of the overall GB consumption of 275 TWh). This was extrapolated out to 2020 using the projections for household demand growth (from both population growth and appliance stock increases per household) from this report. The DECC figures were taken from: S. Khan and S. Stadnyk, “Sub-national electricity consumption statistics: Regional and local authority level statistics (2012 data)”, DECC, 2013.
39. During times of high supply from wind and solar energy, consumers were encouraged to shift their consumption into these periods (low tariff); conversely, electricity became more expensive during a simulated supply shortfall.

40. The following price bands were defined for the LCL trials: high price: 67.2 pence/kWh, medium price: 11.76 pence/kWh, low price: 3.99 pence/kWh, refer to: J. Schofield, R. Carmichael, S. Tindemans, M. Bilton and G. Strbac, “Residential consumer responsiveness to time-varying pricing”, Imperial College Low Carbon London Learning Lab, 2014.


45. Peak times for the sToU trials are shown in Figure 35. For the LCL dToU trial, peak times started at 16:30 or 17:30 and lasted for 5.5 hours (“constraint management” events). For the calculation of the peak demand regarding efficient appliance impacts, the peak period was defined from 17:00 to 22:30 (average of the LCL dToU peak definition).

46. Only lighting, cold and wet appliances, as well as televisions, were considered. The average appliance ownership numbers used in this calculation were taken from those of a typical household in Greater London as per the LCL appliance ownership survey.


<table>
<thead>
<tr>
<th>BAT</th>
<th>Best Available Technology</th>
<th>GLA</th>
<th>Greater London Authority</th>
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<td>CECED</td>
<td>European Committee of Domestic Equipment Manufacturers</td>
<td>GSP</td>
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<td>Heat Pumps</td>
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<td>Compact fluorescent Lamps</td>
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<td>Light Emitting Diodes</td>
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<td>LPN</td>
<td>London Power Networks</td>
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<td>dToU</td>
<td>Dynamic Time of Use</td>
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<td>Load related expenditure</td>
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<td>MW</td>
<td>Mega-Watt</td>
</tr>
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<td>Abbreviation</td>
<td>Description</td>
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<td>EDRP</td>
<td>Energy Demand Research Project</td>
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<td>MwH</td>
<td>Mega-Watt Hour</td>
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<td>Energy Efficiency Commitment</td>
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<td>Northern Ireland Keypad (meter trial)</td>
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<td>Demand Side Response – generation</td>
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Project Overview

Low Carbon London, UK Power Networks’ pioneering learning programme funded by Ofgem’s Low Carbon Networks Fund, has used London as a test bed to develop a smarter electricity network that can manage the demands of a low carbon economy and deliver reliable, sustainable electricity to businesses, residents and communities.

The trials undertaken as part of LCL comprise a set of separate but inter-related activities, approaches and experiments. They have explored how best to deliver and manage a sustainable, cost-effective electricity network as we move towards a low carbon future. The project established a learning laboratory, based at Imperial College London, to analyse the data from the trials which has informed a comprehensive portfolio of learning reports that integrate LCL’s findings.

The structure of these learning reports is shown below:

<table>
<thead>
<tr>
<th>Summary</th>
<th>DNO Guide to Future Smart Management of Distribution Networks</th>
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<tr>
<td>A1</td>
<td>Residential Demand Side Response for outage management and as an alternative to network reinforcement</td>
</tr>
<tr>
<td>A2</td>
<td>Residential consumer attitudes to time varying pricing</td>
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<tr>
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<td>Residential consumer responsiveness to time varying pricing</td>
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<td>A4</td>
<td>Industrial and Commercial Demand Side Response for outage management and as an alternative to network reinforcement</td>
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<td>Conflicts and synergies of Demand Side Response</td>
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<td>Network impacts of supply-following Demand Side Response report</td>
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<td>A7</td>
<td>Distributed Generation and Demand Side Response services for smart Distribution Networks</td>
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<td>A8</td>
<td>Distributed Generation addressing security of supply and network reinforcement requirements</td>
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<td>A9</td>
<td>Facilitating Distributed Generation connections</td>
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<td>A10</td>
<td>Smart appliances for residential demand response</td>
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<td>B1</td>
<td>Impact and opportunities for wide-scale Electric Vehicle deployment</td>
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<tr>
<td>B2</td>
<td>Impact of Electric Vehicles and Heat Pump loads on network demand profiles</td>
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<td>Impact of Low Voltage – connected low carbon technologies on Power Quality</td>
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<td>B4</td>
<td>Impact of Low Voltage – connected low carbon technologies on network utilisation</td>
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<td>B5</td>
<td>Opportunities for smart optimisation of new heat and transport loads</td>
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<tr>
<td>C1</td>
<td>Use of smart meter information for network planning and operation</td>
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<tr>
<td>C2</td>
<td>Impact of energy efficient appliances on network utilisation</td>
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<tr>
<td>C3</td>
<td>Network impacts of energy efficiency at scale</td>
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<tr>
<td>C4</td>
<td>Network state estimation and optimal sensor placement</td>
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<tr>
<td>C5</td>
<td>Accessibility and validity of smart meter data</td>
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<tr>
<td>D1</td>
<td>Development of new network design and operation practices</td>
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<tr>
<td>D2</td>
<td>DNO Tools and Systems Learning</td>
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<tr>
<td>D3</td>
<td>Design and real-time control of smart distribution networks</td>
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<tr>
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<td>D5</td>
<td>Novel commercial arrangements for smart distribution networks</td>
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<td>D6</td>
<td>Carbon impact of smart distribution networks</td>
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