Demand Side Response in the domestic sector- a literature review of major trials

Final Report

Undertaken by Frontier Economics and Sustainability First

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Demand Side Response in the domestic sector- a literature review of major trials

Executive summary

1. Frontier Economics and Sustainability First were commissioned by DECC to review the evidence on Demand Side Response (DSR) trials in the domestic electricity sector, in the UK and internationally.

2. This report focuses on DSR (changes to the time of electricity use), rather than on electricity demand reduction. DSR has the potential to reduce costs and carbon dioxide emissions across the electricity system, allowing more efficient use of existing electricity generation and network capacity. This would reduce the need for investment in new capacity and minimise the use of less efficient generation plant.

3. The importance of DSR is likely to increase as the UK moves to a low-carbon economy. Low-carbon demand-side technologies such as electric vehicles and electric heat pumps may increase both the size of daily peaks in demand and the proportion of demand that can be flexible. At the same time, the need for demand side flexibility is likely to increase as more electricity generation comes from low-carbon technologies, which often have more variable and less predictable output.

4. This report considers two types of DSR:

- **DSR aimed at delivering a reduction in electricity use at peak time on a day-in day-out basis**. This type of DSR involves a habitual change in consumer behaviour during the daily peak period.

- **DSR aimed at delivering a reduction during exceptional, 'critical peaks' in electricity demand.** This type of DSR involves occasional reductions in consumer demand at times of exceptionally high electricity supply costs[1].

5. This report reviews 30 DSR trials in the domestic electricity sector. The initiatives covered a range of countries, seasons, appliance uses, and market arrangements. Some trials included in this review focussed on economic incentives such as time of use tariffs while others included non-economic signals, such as the provision of information. Most trials tested more than one DSR measure (for example different types of tariffs or different combinations of economic measures and automation technologies).

[1] These peaks in costs have generally been driven by demand peaks in the studies reviewed. However, in the future, intermittent generation may increasingly be a driver of cost peaks. For example, as penetration of wind generation capacity in the GB system increases, high costs may be correlated with low wind output. High costs could also be driven by a failure in a plant or in part of the network.

6. Trials were identified through a literature search using an academic database[2], through online searching for grey literature and recent meta-studies.

7. There are four parts to this report:

- Part 1 presents our key findings and sets out the evidence to support each one.
- Part 2 identifies five important areas where the evidence remains inconclusive.
- Part 3 presents the lessons learned on DSR from other sectors.
- Part 4 summarises conclusions for the UK and identifies areas for further research.

Part 1 - Evidence

The review identified four areas where important lessons can be drawn from the evidence.

- **Key finding 1:**
  Consumers do shift electricity demand in response to economic incentives (such as the application of higher prices during peak demand periods) even if these incentives are accompanied by only basic information on the prices being applied, however the size of the shift can vary significantly. Basic information may include provision of fridge magnets displaying peak hours and/or prices, information sheets, and basic bill inserts[3]. This finding applies to both day-in day-out reductions in peak demand and reductions at times of critical peaks:
    - **Day-in day-out DSR:** The size of the shift varies across tariff types and trials (from 0% to 22%).
    - **Critical peak DSR:** The size of the shift varies across tariff types and trials (from 5% to 38%).
- **Key finding 2:**
  Interventions to automate responses deliver the greatest and most sustained household shifts in demand where consumers have certain flexible loads, such as air conditioners or electric heating.
    - **Day-in day-out DSR:** Evidence from the long running Economy 7 scheme in the UK[4] shows that day-in day-out shifting of demand away from peak times can be

2 EBSCO Econlit, http://www.ebscohost.com/academ%C3%ADc/econlit-with-full-text.

3 We separately consider the impact of providing more sophisticated information. More sophisticated information includes real-time and bespoke information.

4 This is a scheme where consumers have a meter to record day-time and night-time (a seven hour period) electricity use, with a lower price for electricity consumed during the night-time period.

sustained through the combination of automation and a tariff signal, especially where consumers have a single flexible load (for example storage heaters)[5].

- **Critical peak DSR:** Where consumers have a large amount of flexible load (such as air conditioners), automation can deliver substantial reductions at critical peaks.

- **Key finding 3:**
After automation, a combination of economic incentives and enhanced information generally delivers the greatest demand response. Enhanced information includes both bespoke information (for example enhanced billing which breaks consumption down into different tariff periods), and technologies or accessories that provide real-time interactive information (such as in-home displays (IHDs) and Energy Orbs).

- **Key finding 4:**
Consumer feedback on tariffs and interventions aimed at encouraging DSR was generally positive.

Part 2 - Inconclusive evidence

8. We have also identified five important areas where the evidence remains inconclusive:

- Findings on the response of vulnerable[6] and low-income consumers to DSR initiatives vary across studies. Some but not all studies found consumers from these groups are less responsive than the average consumer to DSR signals.

- Testing of real-time pricing[7] for households has not produced robust results to date.

- Evidence on the impact of non-economic signals[8] alone is mixed, with findings on the effectiveness of such measures varying across trials.

- There is limited evidence on the way consumers shift their electricity use in response to incentives. For example, with the exception of air-conditioning and storage heating, it is not clear which appliances consumers are willing to use in a flexible way.

- There is limited evidence on whether DSR persists over time if it is not automated or directly controlled[9].

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[5] Not all Economy 7 consumers have automated storage heating.

[6] Vulnerable consumers are defined in the UK Fuel Poverty Strategy 2001 as people with a long-term illness, families with children, disabled people and the elderly, http://www.decc.gov.uk/assets/decc/what%20we%20do/supporting%20consumers/addressing%20fuel%20poverty/strategy/file16495.pdf.

[7] Real-time pricing is retail pricing that varies (generally half hour by half hour) with the wholesale electricity price.

[8] Non-economic signals are those which do not involve price signals. Non-economic signals may include the provision of information and automation.

[9] Direct control allows appliance settings, for example air conditioning cycling, to be directly changed, for example by the energy supplier.

Part 3 - DSR in other sectors

9. Evidence from the water, telecoms and rail sectors indicates that consumers do respond to both economic and non-economic signals by shifting their demand away from daily peaks. This result is consistent with Key finding 1 for electricity demand.

10. There was insufficient information on DSR in other sectors to test the applicability of Key findings 2-4. However other useful insights can be gained from these sectors.

- Evidence from the rail sector suggests that the price charged in the 'shoulder' period should be considered, as well as the price charged in the peak period itself. The shoulder period is the period that occurs directly before and after the peak period. If the price in the shoulder period is too low, new demand peaks may be created when incentives to move demand away from the peak period are applied.

- Evidence from the telecoms sector suggests that consumer sensitivity to DSR signals differs depending on the time of day. It is plausible that this would also apply in the electricity sector.

- One trial in the water sector found that within-day shifts in water use persisted, even after the economic incentive was removed. The extent to which this finding may be applicable to the domestic electricity sector is not clear.

Part 4 - Conclusions for the UK and further research

11. Some conclusions can be drawn directly from UK evidence while evidence in other areas is mixed.

- **Evidence from UK trials on the response of consumers to time of use (ToU) tariffs is mixed**[10]. A response to ToU tariffs was observed in both the *Energy Demand Research Project (EDRP)* trials in Great Britain[11] and the *Powershift trial* in Northern Ireland[12]. However, in one of the two *EDRP* trials, the result only held for households with fewer than three occupants and it has not been possible to establish whether the results of the *Powershift* trial are statistically significant.

- Experience with the Economy 7 tariff in the UK indicates that **some consumers are willing to accept a degree of automation of their electricity use.** Most Economy 7 consumers in the UK already allow remote control of their electric storage heaters.

- UK evidence on the importance of enhanced information to encourage consumers to shift their demand is mixed, with differing results found in the EdF and SSE parts of the *EDRP* trial.

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10 Under ToU the electricity price varies depending on the time of day. ToU tariffs typically have two (peak and off-peak) or three (base, peak and night) rates.

11 AECOM Ltd for Ofgem, 2011, Energy Demand Research Project: Final Analysis.

12 Gill Owen and Judith Ward, Sustainability First, 2007, Smart meters in Great Britain: the next steps? Paper 6: Case studies.

12. Local conditions across international trials are likely to impact on how applicable the findings are to the UK. These conditions include the types of appliances, housing stock, cultural factors and economic conditions. Little information is available within the trial literature on the local characteristics that applied for each trial. However, with the exception of the results on critical peak tariffs (which have been tested mainly on consumers with air conditioners), each of our key messages is supported by evidence from a range of countries, with different local characteristics.

13. We note that the results which apply to air conditioners may also apply to heat pump use in the UK, which is likely to increase in the next decades. There are some similarities between heat pump and air conditioning technologies. The way consumers use both of these technologies may depend on the extent to which they are willing to accept a small reduction in comfort during the peak period.

14. Further research into domestic DSR could be very useful in a number of areas. In particular:

- There is little evidence on **the impact of DSR incentives on low-income and vulnerable consumers.**

- Useful learning could be gained from investigating **consumer behaviour and attitudes in relation to the Economy 7** tariff.

- Further research on **what electricity use consumers actually move** would be useful. The Household Electricity Survey provides data on electricity end use at appliance level and yield insights into behaviour, for example by showing which appliances are typically used during peak periods[13]. This data could provide a basis for further work aimed at understanding more about the flexibility of consumer demand associated with different appliances.

- There is little evidence from the UK **on whether consumer responses to price signals differ according to the strength of the price signal**. Further research in this area would be useful[14].

- Findings on the **response of consumers to non-economic signals alone vary** across trials. Further research in this area may be useful. The extent to which consumers can shift demand may depend partly on the electrical appliances they have. As set out in the Government's Carbon Plan[15], the move to a low-carbon economy is likely to involve increased **electrification of heat and transport**. An understanding of the role of DSR in a low-carbon economy will require further research focussed on the impact of these new technologies on DSR.

Finally, we note that important trials in some of these areas are already planned or are being carried out under programmes funded by the Technology Strategy Board, the Energy

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13 DECC/Defra/EST, 2012, Household Electricity Survey http://randd.defra.gov.uk/Document.aspx?Document=10043_R66141HouseholdElectricitySurveyFinalReportissue4.pdf

14 Research carried out in Ireland on this question found that consumer responses did not differ according to the strength of the price signal. Commission for Energy Regulation, 2011, Electricity Smart Metering Customer Behaviour Trials (CBT) Findings Report

15 DECC, 2011, The Carbon Plan http://www.decc.gov.uk/en/content/cms/tackling/carbon_plan/carbon_plan.aspx

Technologies Institute and Ofgem's Low Carbon Network Fund. **Investment in the regular collation and dissemination of the results from the ongoing trials will be extremely important** and will help to ensure that the results from the trials feed into both ongoing trial design and, ultimately, into policy development.

Introduction

1. As the Government has set out in its Electricity Market Reform White Paper[16] and the Carbon Plan[17], there are a number of significant challenges in delivering a secure, affordable and low-carbon supply of electricity in the coming decades. The Government is committed to halving greenhouse gas emissions, from 1990 levels, by the mid-2020s. Over a quarter of existing electricity generation plant will close by 2020 and much of the replacement capacity will be from intermittent sources such as wind.

2. The Government recognises that a potentially cost-effective way to achieve security of supply is to reduce demand and make better use of existing generation by making the network smarter and more responsive. This is the reason that interventions which increase the responsiveness of the system such as Demand Side Response (DSR), storage and interconnection will have an increasingly important role in helping to tackle the future energy supply challenges.

3. DSR (a short-term movement in the time at which electricity is used) will require consumers to respond to new types of tariff. These tariffs will reflect the variations in electricity generation, transmission and distribution costs throughout the day and will provide incentives for consumers to transfer some of their electricity use to times when electricity can be produced more cheaply.

4. To build our understanding of how consumers respond to more complex tariffs, what incentives have worked well in terms of pricing and engagement, and which barriers inhibit customers from using such tariffs, DECC commissioned Frontier Economics and Sustainability First to undertake a literature review of major DSR trials. This piece of research, alongside further ongoing analysis, will inform the Government's thinking on what action is required to maximise the potential of DSR in the UK.

Why DSR?

5. This report focuses on DSR (shifts in the time of electricity demand), rather than demand reduction[18].

6. DSR can lower electricity costs by reducing the need for investment in new generation, network and system balancing capacity. The level of demand for electricity varies across

16 DECC, 2011, Planning our electric future: a White Paper for secure, affordable and low-carbon electricity

17 DECC, 2011, The Carbon Plan

18 This focus on DSR rather than demand reduction is in contrast to a number of the literature studies that have recently been completed. See for example Ehrhardt-Martinez, Donelly, Laitner 2010, Advanced metering initiatives and residential feedback programs: A meta-review for household electricity-saving opportunities, and Darby, 2010, Literature review for the energy demand research project.

the day and is currently lowest overnight. Because it is expensive to store, electricity is generally generated and supplied to consumers when it is demanded. This means that sufficient electricity generation and network capacity must be in place to meet peak demand. By smoothing the daily demand profile and shifting some of the demand that occurs at peak time to times of lower usage, DSR can reduce the requirements for additional network and generation capacity and thereby save costs.

7. DSR can also save generation costs and emissions by reducing the need to use more costly and emissions-intensive plants. In the electricity sector in Great Britain, plants are brought online in order of running cost[19]. At times of peak demand, the plants with the highest running costs are used but, as well as being more costly to run, these plants often emit more carbon dioxide per unit of electricity generated than plants used at off-peak times[20].

8. The move to a low-carbon economy is likely to increase the importance of DSR.

- Meeting climate change targets will involve the electrification of heat and transport which is likely to increase both peak demand and the amount of demand that is flexible.

- Moving to a low-carbon generation mix will reduce the flexibility and predictability of electricity supply and will increase its variability. This is likely to result in an increased role for the demand side flexibility provided by DSR, given the need to balance supply and demand at each point in time. The move to renewable sources may mean that higher system costs and peak demand no longer coincide. DSR could also therefore have value outside times of peak demand, for example when changes in weather mean that output from wind generation falls or increases.

- Low-carbon plants, such as wind and nuclear, tend to be more capital-intensive than conventional plants, such Combined Cycle Gas Turbines. The potential gains from smoothing demand in a low-carbon generation system could therefore be even greater.

9. DSR can be used to reduce the costs of meeting peak demand and also to bring greater system flexibility[21]. Trials to date have focussed on the former use.

10. Throughout this report, we distinguish between two types of DSR that are used to reduce the costs of meeting peak demand.

- **DSR aimed at delivering a consistent day-in day-out reduction at peak time**. This type of DSR involves a habitual change in consumer behaviour during the daily peak period. The

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19 The GB system has been set so that plants are dispatched in order of their short run marginal costs. Short run marginal cost will include operating costs such as fuel use, but will exclude fixed and capital costs.

20 There are some exemptions to this. For example, if peak demand which would have been met by an inefficient gas-fired peaking plant is instead shifted to an off-peak period when coal-fired plant is generating, a net increase in emissions may result. This is because even the most efficient coal-fired plant will be more emissions-intensive than the least efficient gas-fired plant.

21 For example, DSR can provide system balancing services to the System Operator. Further information on system balancing services is available on the National Grid website: http://www.nationalgrid.com/uk/Electricity/Balancing/. This is happening already in the industrial and commercial sector, although it is low

response is usually required each weekday for a whole winter or summer season[22]. This type of DSR is most useful when systems are characterised by regular peaks of similar sizes.

- **DSR aimed at delivering a reduction during critical peaks.** This type of DSR requires an occasional response from consumers to an exceptional event. Exceptional events may be caused by critical peaks in demand, which usually occur during exceptionally hot or cold periods when electricity use for heating or cooling peaks. Exceptional events may also be driven by the short term failure of a generation plant or part of the transmission or distribution network and may in future be driven by changes in wind generation output.

Methodology

11. The literature included in this review covers recent trials as well as existing meta-analyses of DSR initiatives.

12. Sustainability First and Frontier Economics, identified trials used in recent meta-analyses and searched an academic database using relevant terms[23]. The criteria for selecting the 30 trials included in this project were as follows:

- They studied domestic, rather than industrial or commercial, electricity consumers.
- They focussed on measures to shift, rather than reduce, demand.
- Trials that did not report the results of the DSR measures and demand shifting results from before 2000[24] were excluded.

13. Trials were not excluded based on design. Where available, details of how consumers were selected for inclusion in the trials, and whether or not the reported results were statistically significant, are recorded in Annexe D.

Overview of trials reviewed

14. This report reviews 30 trials of DSR in the domestic electricity sector, most of which tested more than one intervention to promote DSR. The trials covered different geographies, seasons, types of appliances, and market arrangements. These differences

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22 In countries where air conditioning is prevalent, peak demand is higher in the summer. In countries such as the UK, where air conditioning is not prevalent, peak demand occurs in the winter.

23 The Econlit database was used (http://www.ebscohost.com/academ%C3%ADc/econlit-with-full-text). Relevant terms included combinations of "demand side response," with "domestic," "electricity," "trial," and "results," "evaluation," "impact assessment" and "analysis." Specific DSR measures were also included for some of the searches, including "time of use tariffs," "critical peak pricing" and "critical peak rebates."

24 Results for the Tempo tariff were also included in our analysis. The tariff continued running after 2000, but results were only available for the trial period, which was before 2000.

should be taken into account when drawing conclusions from direct comparisons across trials.

15. Key European trials have included the *Energy Demand Research Project (EDRP)* trials in Great Britain, the *Ireland Electricity Smart Metering Trials*[25], and trials in Norway and France. However, the literature is dominated by recent trials in North America and, to a lesser extent, Australia. Cooling requirements are greater in these countries and many of these studies focussed on the behaviour of consumers with air conditioning which, although less directly relevant to DSR in the UK, present parallels with heat pumps, which have similar technical characteristics and are likely to become more widespread in the UK as it moves to a low-carbon economy. Both heat pumps and air conditioning units represent a significant source of electricity demand and there are limits to the amount of demand which can be moved before affecting consumers' comfort.

Report structure

16. This report covers four areas:

- Part 1 presents the four key findings identified in the review and sets out the evidence to support each one.
- Part 2 identifies five important areas where the evidence remains inconclusive.
- Part 3 presents the lessons learned on DSR from other sectors.
- Part 4 summarises conclusions for the UK and identifies areas for further research.

[25] Commission for Energy Regulation, 2011, Electricity Smart Metering Customer Behaviour Trials (CBT) Findings Report.

Part 1 - Evidence from DSR trials

Key finding 1:
Consumers do shift demand in response to economic incentives even if the incentives are accompanied by only basic information, however the size of the shift varies significantly across tariff types and trials.

17. The literature shows that economic incentives are effective in changing consumer behaviour. Consumers respond to static time of use (ToU), Critical Peak Pricing (CPP) and Critical Peak Rebate (CPR) price signals by reducing their electricity demand at peak periods.[26,27]

18. The results referred to in this section all relate to economic incentives accompanied by only basic information on the tariff rates. Basic information may include provision of fridge magnets displaying peak hours and/or prices, information sheets, and basic bill inserts. We look at the provision of more sophisticated information measures in a later section (see paragraphs 64-70)[28].

Day-in day-out DSR

19. Under ToU tariffs, prices differ according to the time of day. Typically there are two (peak and off-peak) or three (base, peak and night) different prices applied to fixed periods during the day. Tariffs are pre-determined and fixed in advance. The aim of implementing these tariffs is to encourage consumers to reduce demand day-in day-out during regular peak periods. This demand could be shifted into the lower priced periods of the day, for example if consumers change the time at which they use appliances.

20. This report looks at fifteen studies which considered the impact of ToU tariffs, accompanied by only basic information. These are set out in Table 1.

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26 Under CPP, a high peak price is applied during critical peak events. Under CPR consumers are paid a rebate for reducing energy use below their baseline use during the critical peak events.

27 Some trials also used real-time pricing. The results are addressed in Part 2.

28 Enhanced information may be bespoke (for example enhanced billing that breaks consumption down into different periods) or include more interactive real-time information (for example Energy Orbs that provide real-time reminders of tariff periods, or In-Home Displays).

Table 1: Summary details for the time of use trials investigated

Trial	Country	Number of participants	Average reduction in peak demand	Peak to off-peak price differential (approximate)
California State-wide Pricing Pilot (2003-2004)	USA	226	1-6%	200%
CL&P Pilot (2009)	USA	188	2-3%	208-408%
PG&E's Trial (2008-2010)	USA	86,222	11%	varied
Ireland Electricity Smart Metering Behaviour Trials (2009-2010)	Ireland	2,920	7-12%	143-271%
Ontario Smart Price Pilot (2006-2007)	Canada	124	0%	140%
myPower Trial (2006-2007)	USA	379	3-6%	187%
Energy Demand Research Project Trials (2007-2010)	UK	194 (EdF Energy), 1,352 (SSE)[29]	varied	165%
Norway EFFLOCOM Trial (2001-2004)	Norway	237	Maximum 10%	unknown
Northern Ireland Powershift trial (2003-2004)	Northern Ireland	100	Small reduction	267%

29 The total number of households with an "incentive to shift" in the SSE trial was 1,352. It is not clear if all of these households were on the ToU tariff, or whether the incentive to shift also included other types of intervention.

Trial	Country	Number of participants	Average reduction in peak demand	Peak to off-peak price differential (approximate)
Integral Energy Trial (2006-2008)	Australia	241	unknown	unknown
Xcel Energy Trial	USA	2,900 in the overall study	5.19% with central air conditioning, 10.63% without	unknown
Florida Gulf Power Select Programme (2000 onwards)	USA	Unknown for the ToU tariff, 2,300 for the CPP tariff	Unknown for the ToU tariff, 22% for CPP consumers during non-critical peak periods	266% for the CPP rate on non-critical days
Idaho DSR trial (2005-2006)	USA	85	0%	184%
Missouri CPP trial (2004-2005)	USA	91	0%	349%
PSE's ToU trial (2001-2002)	USA	300,000 residential and small commercial	5%	unknown

21. **A reduction in peak demand was achieved under ToU tariffs in most studies**[30]. Only three studies (the *Ontario Smart Price Pilot*[31], *Idaho DSR trial*[32] and *Missouri CPP*

30 The results of the Norwegian ToU trial reported are excluded as they gave maximum rather than average responses. The ToU trial in Northern Ireland is also excluded as the percentage reduction in peak demand was not reported.

31 IBM Global Business Services and eMeter Strategic Consulting, 2007, Ontario Energy Board Smart Price Pilot Final Report.

32 Faruqui and Sergici, 2009, Household Response to Dynamic Pricing of Electricity- A Survey of the Experimental Evidence.

trial[33]) found no reduction in peak period energy use for consumers on ToU tariffs. The information in the published studies does not allow these results to be conclusively explained[34].

22. **The range of peak period demand reductions found in trials of ToU tariffs alone was large.** This is illustrated in Figure 4 in Annexe A. We discuss reasons for these variations below, in paragraphs 48-51.

23. Given the different conditions across countries, the most relevant trials for the UK context are the *EDRP* trials. These include the SSE trial, which looked at the application of a ToU signal accompanied by basic information[35]. This trial recorded a small reduction in peak demand[36].

Critical peak DSR

24. Two types of tariffs designed to reduce critical peak demand were trialled: CPP and CPR. CPP tariffs apply a pre-determined high price during times of exceptionally high demand or 'critical peaks'. CPR tariff consumers receive a rebate for reducing energy use below their baseline use during the critical peak events. The dates of critical peak events are not known in advance[37]. CPP and CPR tariffs must therefore include a mechanism to notify consumers when the energy supplier intends to implement a critical peak.

25. Critical peak periods tend to occur during the usual peak period on week days. In the trials reviewed, a set number of critical peak events (often twelve) were allowed per season or year, and consumers were notified shortly before the high peak price was to be applied. Notifications were typically sent the day before by phone, text or email, and some trials supplemented this with real-time reminders on the day.

26. Most of the CPP and CPR tariffs reviewed were accompanied by a ToU tariff. This meant that while consumers faced a signal to reduce their demand at peak every day, on critical peak days they faced an even stronger signal to shift demand. However, a limited number of CPP and CPR tariffs were overlaid on a rising block tariff (where per unit prices increase with total consumption). For consumers on this type of tariff, critical peak days were the only times when they faced a price signal to shift demand. Some trials

33 RLW Analytics for Corporate Planning AmerenUE, 2006, Ameren UE Residential ToU Pilot Study, Load Research Analysis - 2005 Program Results.

34 We note that this was a relatively small trial, with just 124 participants, although trial participants were recruited by a stratified random sample and so should form a representative sample.

35 The EdF trial also looked at a ToU tariff. The results of this trial are discussed under Key Message 2, as the EDF trial combined a ToU tariff with an in-home display.

36 The results of the ToU tariff alone are not reported separately in the trial literature. However the report states: "The percentage of consumption that falls in the [weekday] peak period is reduced by the incentive to shift but only by a small amount from 19.8% to 19.5%. The effect of the incentive to shift was greater in the absence of an RTD or in the absence of web information". p. 105, AECOM Ltd for Ofgem, 2011, Energy Demand Research Project: Final Analysis.

37 The factors that determine when critical peaks occur may differ across trials. In some trials the energy supplier may call critical peaks when temperatures exceed a certain threshold in summer.

also used variable rather than fixed peak pricing, where the critical peak price was not set in advance of critical peak events being called[38].

27. We reviewed sixteen trials which looked at CPP tariffs and five trials which looked at CPR tariffs where only basic information was provided. The details of the trials are summarised in Table 2.

Table 2: Summary details for the critical peak pricing and critical peak rebate trials investigated

Trial	Country	Number of participants	Average reduction in critical peak demand	Critical peak price or rebate to off-peak price differential (approximate)
CPP - Critical Peak Pricing				
California State-wide Pricing Pilot (2003-2004)	USA	827 (CPP-Fixed Critical Peak period), 234 (CPP-Variable Critical Peak Period)	13%	unknown
CL&P Pilot (2009)	USA	371	10-16%	720-2019%
Integral Energy Trial (2006-2008)	Australia	297	37%	2008%
Energy Australia Trial (2006-2008)	Australia	~750	7%	3636%
PG&E Trial (2008-2010)	USA	~24,500 on SmartRate	14-15%	varied
BGE Pricing Pilot (2008)	USA	148	20%	1444%

38 An additional variation on typical CPP tariffs is the EdF Tempo tariff. This is a dynamic ToU tariff with a fixed number in any year of each of three different types of day. These are blue (normal), white (mid-peak) and red (high-peak), and the type of day is determined one day in advance. Both peak and off-peak prices are higher on red or white days than on blue days.

Trial	Country	Number of participants	Average reduction in critical peak demand	Critical peak price or rebate to off-peak price differential (approximate)
ETSA Utilities Trials (2005-2010)	Australia	20	unknown	unknown
myPower Trial (2006-2007)	USA	379	14%	850%
Ontario Smart Price Pilot (2006-2007)	Canada	124	25%	400%
PowerCentsDC Trial (2008-2009)	USA	233	22-29%	688%
OG&E Trial (2010)	USA	3,000+ overall	12%	1095%
EdF Tempo Tariff	France	800 at the experimental stage	45%	Unknown
Xcel Energy Trial	USA	2,900 in the overall study	Without air conditioning: 32% for CPP, 15% for CPP-ToU With air conditioning: 38% for CPP, 29% for CPP-ToU	Unknown
Florida Gulf Power Select Programme (2000 onwards)	USA	2,300	41%	829%
Idaho DSR Trial (2005-	USA	68	1.26kW per hour during	370%

Trial	Country	Number of participants	Average reduction in critical peak demand	Critical peak price or rebate to off-peak price differential (approximate)
2006)			critical peaks	
Missouri CPP Trial	USA	87	12% (2004), 13% (2005)	625%
CPR - Critical Peak Rebate				
CL&P Pilot (2009)	USA	382	7-11%	unknown
BGE Pricing Pilot (2008)	USA	253	18-21%	773-1167%
Ontario Smart Price Pilot (2006-2007)	Canada	125	18%	400%
PowerCentsDC Trial (2008-2009)	USA	318	6-11%	682%
Anaheim Critical Peak Rebate Trial (2005)	USA	71	12%	519% for consumption below 240kWh per month

28. **A reduction in peak demand was achieved in all CPP and CPR tariff studies**. Figure 5 and Figure 6 in Annex A present the results of the trials of CPP and CPR tariffs accompanied by only basic information. These show that a reduction was found in all cases.

29. **The range of peak period demand reductions found in trials of CPP and CPR tariffs was large.** CPP tariffs achieved a reduction in peak period electricity demand in all trials. The range of average critical peak period demand reductions was between 5% and 38%. The largest reductions were found for consumers with central air conditioning in the *Xcel*

Energy Trial[39] where the average critical peak demand reduction was 38%, and the *Integral Energy Trial*[40] in Australia, where the average critical peak demand reduction was 37%. The price ratio was not available for the *Xcel Energy Trial.* In the *Integral Energy Trial*, the CPP tariff was just over 2000% more than the off-peak price, which is towards the high end of the range of differentials used in CPP schemes. The smallest peak period demand reductions were also seen in Australia, in the *Energy Australia trial*[41] where one of the peak to off-peak price differentials used was even higher, at around 3600%.These two trials were designed and implemented separately. It is not clear from the published material what is driving the difference in results.

30. The range of average demand reductions found in trials of CPR tariffs was similar, between 6% and 21% for those trials that did not include automation or additional engagement technologies.

31. **Within trial comparisons[42] of CPP and CPR tariffs showed that load shifting was higher for CPP tariffs than for CPR tariffs.** Figure 7 in Annexe A shows this result held in the *CL&P Pilot*[43], in the *PowerCents DC Trial*[44] in Washington DC, and in the *Ontario Smart Price Pilot*.

32. We can rule out two potential drivers of this result.

- Differences in the levels of economic incentives within these trials are unlikely to be driving the result. For example, the CPP and CPR tariffs introduced in the *PowerCents DC trial* and the *Ontario Smart Price Pilot* were both designed to be cost neutral on average for trial participants[45].

- Biased samples are unlikely to be driving the result. The *PowerCents DC Trial* included 900 consumers who were randomly selected to participate in one of the types of tariff being trialled. The 373 participants in the *Ontario Smart Price Pilot* were similarly randomly selected for one of the tariffs being trialled.

33. The reports do not provide enough evidence to conclusively explain the stronger response to CPP tariffs, but it may be due to the following:

- Consumers may find rebates more difficult to understand than higher prices, since rebates are calculated relative to a consumer's notional baseline demand (what their electricity demand would have been expected to be during the critical peak, in the absence of a critical

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39 Faruqui and Sergici, 2009, Household Response to Dynamic Pricing of Electricity- A Survey of the Experimental Evidence.

40 Energy Market Consulting Associates, 2009, Smart Meter Consumer Impact: Initial Analysis.

41 Energy Market Consulting Associates, 2009, Smart Meter Consumer Impact: Initial Analysis.

42 "Within trial" comparisons refer to evidence found in a single trial, and comparisons "between trials" refer to evidence found in separate trials.

43 Connecticut Light and Power, 2009, Results of CL&P Plan-It Wise Energy Pilot.

44 eMeter Strategic Consulting, 2010, PowerCentsDC Program Final Report.

45 Average cost neutrality means that consumers on average will be not better or worse off from the trial but that some consumers may still experience higher bills as a result of the tariff. Some trials (for example the Ireland Electricity Smart Metering Trials and the Ontario Smart Pilot) also undertook to guarantee that individual consumers would not face higher bills as a result of participating in trials, by providing them with an adjusted subsidy payment at the end of the trial period

peak tariff)[46].This may make it difficult for consumers to estimate the savings they make from shifting demand away from the peak[47].

- Consumers may be loss averse. That is, they may care more about the additional costs that they incur with CPP tariffs than about the additional gains they may make with CPR tariffs. Loss aversion has been observed by behavioural economists in other contexts[48].

Comparison between the results of ToU, CPP and CPR trials

34. Looking across trials that tested ToU, CPP and CPR tariffs, it is possible to assess the importance of the strength of the price signal in delivering DSR. The greater the difference between peak and off-peak prices in percentage terms, the stronger the price signal is considered to be.

35. **Comparing across trials, the size of the difference between peak and off-peak prices does not fully explain the variation in the size of the consumer response across studies**. Figure 4 and Figure 5 (in Annexe A) illustrate that there is not a strong relationship between the size of the difference between peak and off-peak prices and the size of the consumer response across studies. This conclusion is consistent with the findings of a recent paper by Faruqui and Palmer which used data on 74 DSR pricing experiments (i.e. different tariff and technology combinations within a given trial) from 9 DSR trials. This study estimated that approximately half the variation in peak period demand reductions recorded in ToU, CPP and CPR trials could be explained by variations in the peak to off-peak price ratio[49].

36. There is a range of other factors that may be driving the differences in results between trials.

- Consumers may become less responsive to economic signals as the duration of the peak period increases. Most trials included a peak period covering around 5 hours. The *CL&P Pilot* included an 8 hour peak period and found only a small peak period demand reduction of 2-3%, despite trialling the highest peak to off-peak differential of the trials reviewed. In consumer feedback after this trial, the length of the peak period was considered by some respondents to be a barrier to shifting demand.

- Consumers may be responding to the introduction of a signal to shift demand, as well as to the strength of the signal itself. It is plausible that the strength of the economic signal would become more important over time as consumers learn about the effect of their changed behaviour on their bills. However, it is not clear from the trial evidence whether this is the case. Persistence of demand shifting is discussed in a later section (see paragraph 91).

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46 Baseline demand is estimated for each consumer. This is typically calculated as the average of the consumer's actual demand during peak hours on certain pre-trial days.

47 CPR consumers were typically provided with information about the pricing programme online and via leaflets. The BGE Pricing Pilot provided CPR consumers with a savings report after critical peak events, which outlined their savings during the previous critical peak and during the programme as a whole.

48 Loss aversion has been demonstrated in field studies and experiments. See for example: Tversky and Kahneman, 1991, Loss *Aversion in Riskless Choice: A Reference-Dependent Model.* The Quarterly Journal of Economics, Vol. 106, No. 4, pp. 1039-1061

49 Faruqui, and Palmer, 2012, The Discovery of Price Responsiveness- A Survey of Experiments involving Dynamic Pricing of Electricity. Unpublished paper submitted to the EDI Quarterly. 32 of the pricing experiments also included an enabling technology.

- Different consumer appliances or housing stock may play a role in the extent of demand response. For example, responses were high in some of the Californian trials, where use of central air conditioning is high. We look into the evidence on appliance use in a later section (see paragraphs 89-90).

37. Some trials tested more than one tariff type. It is therefore possible to assess the importance of the peak to off-peak differential within individual trials.

38. **Comparing within trials, evidence on the importance of the size of peak to off-peak price differentials is mixed for ToU tariffs, but points towards higher differentials resulting in higher peak demand reductions for critical peak tariffs.**

- For ToU tariffs, evidence from within trials on whether larger peak to off-peak differentials result in larger demand reductions is mixed. Peak demand reductions under a ToU tariff were higher with a greater peak to off-peak differential in the *CL&P Pilot (*Figure 4, points 4 and 7) while the increase in the price differential had no effect in the *Ireland Electricity Smart Metering Trials (*Figure 4*,* points 10-12). It is not clear what is driving the difference in these findings.

39. For CPP and CPR tariffs, studies that trialled high and low peak to off-peak tariff differentials found larger demand reductions for higher price differentials. This was the case in both the *BGE Pricing Pilot (*Figure 6*,* points *6-7)*[50] and the *CL&P Pilot (*Figure 5 points *3-9* and Figure 6 points *2-3)*.

40. **Comparing across tariffs with different aims, it is clear that critical peak tariffs have a greater impact than ToU tariffs on peak demand on the days that the response is called.** This is illustrated by Figure 1 which shows that the average response is higher under CPP and CPR than under ToU tariffs. This is to be expected, given the characteristics of these tariffs, and their differing aims.

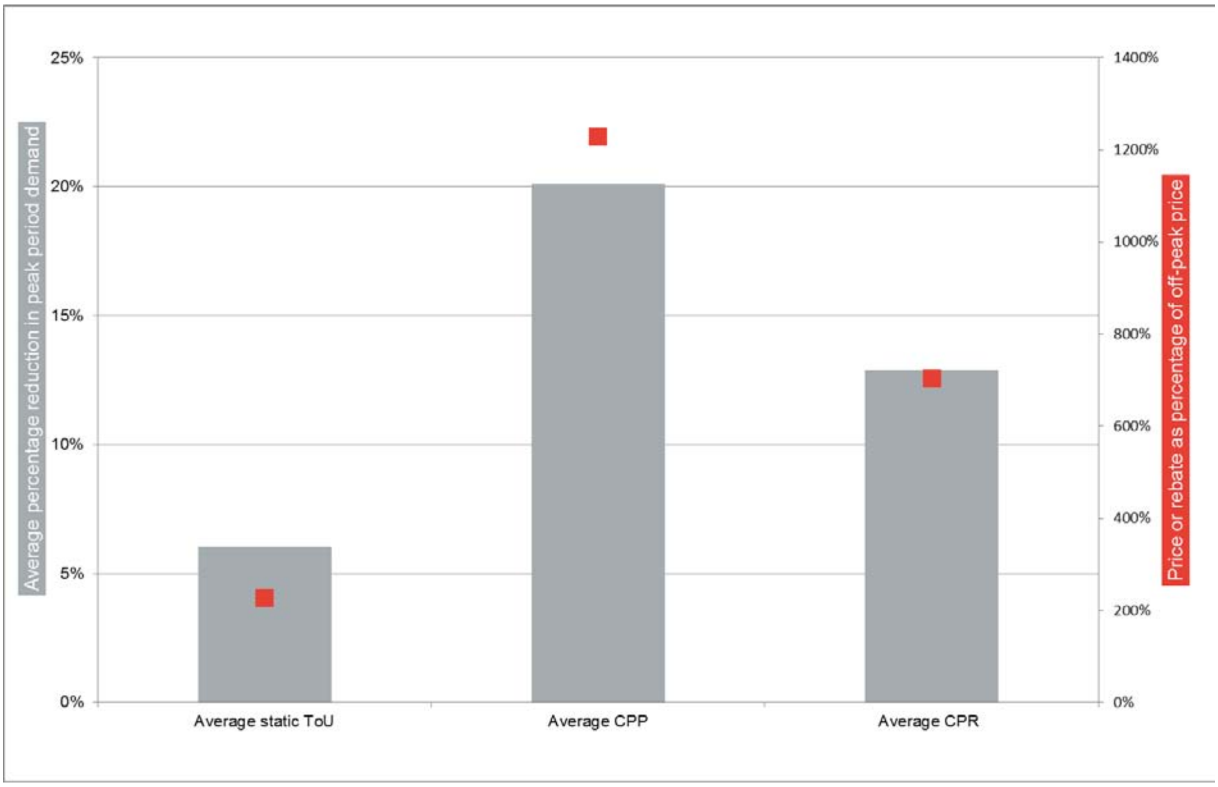
- The critical peak events under CPP and CPR tariffs occur infrequently (usually around 12 times a year), while the ToU signal is in place on a daily basis. Consumers may be more content to shift their demand occasionally than to shift it on a regular basis.

- The price signals are significantly stronger on average under the CPP and CPR tariffs, and these tariffs are often overlaid on a ToU tariff.

- Under CPP and CPR, there is a requirement to notify consumers of the critical peak in advance, which acts as a reminder to take action.

50 Faruqui and Sergici (The Brattle Group), 2009, BGE's Smart Energy Pricing Pilot, Summer 2008 Impact Evaluation.

Figure 1: Comparison of demand reductions and peak to off-peak price differentials



Consumer engagement

41. In all trials, consumers were provided with basic information about the different rates which applied at different times[51]. This information was provided in different ways across trials including through magnets or stickers displaying peak periods and/or prices, and information packs on the tariffs and how to reduce or shift demand.

42. Of the basic information types, consumers appear to favour fridge magnets and stickers. Feedback from the *Ireland Electricity Smart Metering Trials* showed that 75% found the fridge magnet useful and 63% found the sticker useful. In the *Ontario Smart Price Pilot*, the fridge magnet (as well as the monthly usage statement) was rated the most useful resource for understanding the tariffs, above the fact sheet, brochure, and other communication materials. Reasons for preferring magnets included that they were clear, concise, and durable.

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51 Some trials provided enhanced information. We discuss these in paragraphs 64-70.

Key finding 2:
Interventions to automate responses deliver the greatest and most sustained household shifts in demand, where consumers have certain flexible loads such as air conditioners and electric heaters.

43. Some trials tested automation and direct control.

- Automation involves the application of a technology which automatically reduces electricity consumption from a given appliance during peak hours. For example a thermostat on an air conditioning unit can be programmed to reduce energy use during times of peak electricity supply costs. In the trials reviewed, automation was mainly applied to air conditioning, though it was also used for electric space and water heating and pool pumps. Automation can be used to deliver day-in day-out or critical peak reductions in demand.

- Direct control allows appliance settings, for example air conditioning cycling[52], to be directly changed, for example by the energy supplier[53]. Direct control is usually applied at times of critical peak.

44. This report looks at 12 trials which included a degree of automation or direct control. These are summarised in Table 3.

Table 3: Summary details for the trials including automation or direct control

Trial	Country	Number of participants	Type of automation or direct control
CL&P Pilot (2009)	USA	209	Controlling technologies for air-conditioning.
PG&E Trial (2008-2010)	USA	~20% of the 25,500 consumers on SmartRate	Controlling technologies for air-conditioning
LIPA Edge Direct Control Programme (2001-2003)	USA	20,400	Smart thermostats allowed direct control of air-conditioning units.
PowerCentsDC Trial (2008-2009)	USA	~1/3 of participants with central air	Smart thermostats allowed direct control of air-conditioning units in

52 Cycling reduces the electricity use of the appliance by switching the compressor on and off, while air already cooled by the unit is still circulated.

53 In theory other parties such as Distribution Network Operators, aggregators or Energy Service Companies (ESCOs) could play this role.

Trial	Country	Number of participants	Type of automation or direct control
		conditioning or electric heating	response to real-time signals
myPower Trial (2006-2007)	USA	319	Programmable thermostats for air-conditioning that could automatically respond to CPP events and ToU tiers
Norway EFFLOCOM Trial (2001-2004)	Norway	1,230	Low prioritised loads (electric water heating) could be disconnected by the energy supplier under certain criteria
SCE Direct Load Control Trial (2010)	USA	343,566 on the summer discount plan	Limiting of the compressor on air conditioning during high system peak hours
OG&E Trial (2010)	USA	3,000+ overall	Thermostats for air-conditioning programmed to respond to price changes
BGE Pricing Pilot (2008)	USA	342	A switch allowing the energy supplier to cycle central air conditioners
ETSA Utilities Trials (2005-2010)	Australia	946	External cycling of air conditioning.
California Automated Demand Response Trial (2004-2005)	USA	122 (2004), 98 (2005)	A system that allowed automation of appliances including pool pumps.
Missouri CPP Trial (2004-2005)	USA	78	A smart thermostat for air-conditioning.

45. Most of these trials aimed to reduce demand at critical peaks, rather than on a day-in day-out basis. It can be seen from this table that automation has only been applied where a large amount of potentially flexible load, such as a central air conditioning unit, is present.

46. Automation has also been applied in the UK under the Economy 7 tariff[54]. **Automation of storage heaters under the Economy 7 tariff provides evidence that some consumers in the UK are willing to accept regular automation of flexible loads.**

- Automation of storage heater load under the Economy 7 tariff is an example of a system that is already in place in the UK to achieve day-in day out DSR. The Economy 7 tariff is targeted mainly at consumers with old-style electric storage heating. Under this tariff, consumers pay less for electricity used after midnight, but often pay more for their day-time units. Many Economy 7 consumers allow their storage heater to be remotely controlled by radio signals within the night time period.[55]

- Sustainability First estimate that around 3-3.5 million households are on an Economy 7 tariff (based on information from energy suppliers), although 5 million have a meter capable of being supplied on an Economy 7 basis[56].

47. The international evidence shows that automation and direct control have resulted in significant responses to critical peaks.

- According to the *Vaasa ett meta-study*[57] of DSR pilots, peak energy demand reductions under ToU, CPP and CPR tariffs are 60-200% greater with automation and/or direct control than without. This meta-study found that peak period demand reductions were 31% after automation (16% before) for CPP tariffs, 20% (12% before) for CPR tariffs, and 16% (5% before) for ToU tariffs.

- Results from the Faruqui and Palmer review also show that percentage reductions in peak period demand are greater with enabling technology, including automation[58] than without. This holds for ToU, CPP and CPR tariffs.[59]

- The *LIPA Edge Direct Control Programme*[60] applied automation without an accompanying peak price signal. Air conditioning units were externally controlled during critical peak events while the tariff structure remained unchanged,[61] so consumers had only a non-economic incentive to shift their demand. Consumers in the trial had the ability to override and there

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54 Information on the Economy 7 tariff is available here: http://www.decc.gov.uk/assets/decc/statistics/publications/trends/articles_issue/1_20100324125048_e_@@_variationtarifftypes.pdf

55 Sustainability First, forthcoming 2012. Paper 3b for GB Electricity Demand project. 'What demand side services could customers offer: household demand'.

56 Sustainability First, forthcoming 2012.

57 Vaasa ett, 2011, The Potential of Smart Meter Enabled Programs to Increase Energy and Systems Efficiency: A Mass Pilot Comparison; Short name: Empower Demand. Available at http://www.esmig.eu/press/filestor/empower-demand-report.pdf. (Accessed 24/01/12)

58 This study does not explicitly define enabling technology, but provides examples such as "In-Home Displays, Energy Orbs and programmable and communicating thermostats" (p.1, Faruqui and Palmer, 2012, The Discovery of Price Responsiveness- A Survey of Experiments involving Dynamic Pricing of Electricity. Unpublished paper submitted to the EDI Quarterly).

59 Faruqui and Palmer, 2012, The Discovery of Price Responsiveness- A Survey of Experiments involving Dynamic Pricing of Electricity. Unpublished paper submitted to the EDI Quarterly.

60 Crossley (Energy Futures Australia), 2010, International Best Practice In Using Energy Efficiency and Demand Management to Support Electricity Networks.

61 Residential participants were offered a $25 incentive for participating, and a $20 incentive for referring new participants.

was no financial penalty associated with this. There is some evidence that overriding rates were low, despite the lack of financial penalty. During a curtailment event in August 2002, 20.8% of consumers had chosen to override the automated reduction in their air conditioning usage by the end of the peak period. Low rates of overriding could be due to consumer inertia, which has been observed by behavioural economists in other sectors. Inertia in this context can refer to the tendency of consumers not to opt out of schemes in which they have been included, even if they would not have actively opted in to these schemes. For example, studies have found that when consumers are automatically enrolled in retirement savings plans (with the possibility of opting out), participation rates in the plans are much higher than when consumers are required to opt in to these plans[62].

- The *CL&P Pilot* tested CPP tariffs with and without automation. It found that CPP tariffs combined with automation reduced peak demand by 23% compared to 16% with CPP tariffs alone. However, combining the ToU tariff with automation did not increase the reduction in peak demand. As noted earlier, the extended duration of the peak period under the ToU tariff may have limited the ability of consumers to shift demand even with automation (where consumers chose to override).[63]

Automation and consumer engagement

48. Once they are on an automated scheme, consumers do not have to adjust their behaviour to respond to price signals. The key behavioural issues relate to the extent to which they accept the scheme in the first place and remain on it, and the extent to which they override the signal, where this is possible.

49. There is currently limited evidence on consumer acceptance of automation. Further GB evidence on this is likely to become available as the results of Ofgem's Low Carbon Network Fund[64] trials are reported over the next few years. The limited evidence suggests that consumers generally accepted automation and direct control. The results of some trials suggest that initial doubt about participation can be mitigated by providing consumers with the options to override any automated response.

- The *SCE Direct Load Control Trial*[65] allowed consumers to choose the maximum number of days per year that their air conditioning could be directly controlled and the degree to which electricity demand from their air conditioning unit could be reduced. Economic incentives were used to encourage consumers to allow a greater degree of direct control. It is not clear how this affected the outcome of the trial relative to other trials. This is because the results were presented per air conditioner, while in other trials they were presented for overall peak electricity demand.

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62 See for example: Thaler R and Benartzi S, Save More Tomorrow: Using Behavioral Economics to Increase Employee Saving, Journal of Political Economy, 2004, vol. 112, no. 1, pt. 2

63 Automation may also have a small effect where consumers choose to override the automation, or where they don't use the technology in the first place, which could result if they do not receive help with installation and how to use the technology.

64 http://www.ofgem.gov.uk/networks/elecdist/lcnf/pages/lcnf.aspx

65 Freeman, Sullivan & Co., 2011, Southern California Edison's 2010 Demand Response Load Impact Evaluations Portfolio Summary.

- A study of consumer acceptance of smart appliances[66] provides further evidence on consumer attitudes to automation and direct control. This study used survey data, phone interviews and focus groups in Austria, Germany, Italy, Slovenia and the UK. The results may not be representative of the population as a whole because the overall sample had "a high share of males, middle-aged people with higher education, a technical background and high ecological awareness, with the majority living in a house without children (about 60%)"[67]. The survey found that consumer acceptance of smart appliances was high among this group, averaging over 90%. **The degree of demand shifting that was acceptable varied across household appliances.**

- 77% of consumers would accept a shift of three hours for washing machines and tumble dryers, but they were concerned about leaving laundry for a longer time as it might go mouldy or become creased.

- For dishwashers, 77% would accept a shift of at least three hours, and the main concern about smart operation was noise during the night.

- There were some objections to smart operation of fridges and freezers due to concerns about safety and the potential for a reduction in food quality[68].

- The Electricity Policy Research Group (EPRG) survey[69] asked consumers about their willingness to accept automation of certain appliances. Respondents were presented with four scenarios that would alter their appliance use. These scenarios included the interruption of electricity demand from fridges and freezers and the setting of timers for wet appliances (dishwashers, washing machines, and tumble dryers) use. Respondents were asked if they would accept these scenarios for a 5% discount on their electricity bill. Reported willingness to accept automation was highest for the interventions affecting fridges and freezers and lowest for those affecting cookers.

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66 Mert et al, 2008, Consumer acceptance of smart appliances. The report does not explicitly define "smart appliances," but as it assesses their role in load management, it has been taken to mean household appliances whose operation can be automated in some way.

67 Mert et al, 2008, Consumer acceptance of smart appliances, p.16.

68 These were to some extent due to a lack of understanding of smart operation of these appliances, which could be addressed by the temperature being more visible on the appliance.

69 Platchkov, Pollitt, Reiner and Shaorshadze, 2011, 2012 EPRG Public Opinion Survey: Policy Preferences and Energy Saving Measures. Available at http://www.econ.cam.ac.uk/dae/repec/cam/pdf/cwpe1149.pdf (Accessed 02/04/12)

Key finding 3:
After automation, a combination of economic incentives and enhanced information generally delivers the greatest demand response.

50. All trials using economic incentives need to provide basic information on tariff levels to trial participants, for example through bill inserts or fridge magnets. Some trials also provided more sophisticated information alongside economic incentives, including:

- additional bespoke information, such as enhanced billing that breaks consumption down into the different tariff periods; and
- accessories that provided more interactive real-time information, such as In-Home Displays (IHDs) and Energy Orbs[70].

The cost of these types of information is typically higher than the cost of providing basic information (such as fridge magnets). Any comparison of the relative merits of the different measures should take this into account.

Bespoke information

51. **Limited evidence on bespoke information provision suggests that it can improve the response to economic signals.** Bespoke information was tested in the *Ireland Electricity Smart Metering Trials* and the *PowerCents DC Trial*.

- The most successful combination of measures in the *Ireland Electricity Smart Metering Trials* included bespoke information. The combination of the bi-monthly bill, bespoke energy statement and electricity monitor were the most successful at reducing peak electricity use in this trial, delivering an 11.3% reduction, compared to an average reduction across intervention types of 8.8%. It is not possible to estimate the impact of the bespoke billing and information alone from the trial results.
- In the *PowerCents DC Trial*, participants received an "Electric Usage Report" setting out daily usage graphically. Survey evidence suggests that this intervention was important. Only 3% of participants said they did not read their Electric Usage Report. 52% said the Electric Usage report helped them save on their bills. Only one in nine participants said they made no change to their electricity use following review of their Electric Usage Report.

Real-time feedback to consumers

70 An Energy Orb is a type of in-home display which glows different colours to signal which tariff periods are in place, and may also change colour to notify consumers in advance of a peak period.

52. Trials provided real-time-information to consumers through in-home displays (IHDs) that show current energy use and billing information or through devices such as Energy Orbs that serve as a real-time visual reminder (and sometimes also a prior warning system) of peak periods to consumers. This report looked at six trials that provided real-time information to consumers. These are summarised in Table 4 and the results of are summarised in Figure 7 in Annexe A**.**

Table 4: Summary details for the trials including real-time information

Trial	Country	Number of participants	Type of DSR initiative
CL&P Pilot (2009)	USA	307	Energy Orbs and IHDs
Integral Energy Trial (2006-2008)	Australia	289	IHDs
BGE Pricing Pilot (2008)	USA	620	Energy Orbs
OG&E Trial (2010)	USA	3,000+ overall	IHDs
Ireland Electricity Smart Metering Trials (2009-2010)	Ireland	938	IHDs
EDRP Trials (2007-2010)	UK	194 (EdF Energy), 588 (SSE)[71]	IHDs

53. **UK evidence on the impact of IHDs is mixed.** The *EDRP* included two ToU trials – the EdF and SSE trials, both of which provided participants with IHDs. The IHD given to consumers in the EdF ToU tariff trial was the most basic trialled by EdF. It was mains connected and provided information on current electricity use, its cost, historic usage data, and CO2 emissions. The SSE IHD was a clip-on device.

- The EdF ToU tariff trial found that a ToU tariff only reduced weekday evening peak demand for households with less than three occupants. ToU tariff weekday peak consumption was 11% lower than consumption in the control group with nobody aged 16-64 in the household, 7% lower with one person and 3% lower with two people[72]. With three or more people in the household, peak consumption under the ToU tariff was actually greater than that in the control

71 There were 588 households in the SSE trial with an IHD and the "incentive to shift."

72 These figures were calculated from the results reported in AECOM Ltd for Ofgem, 2011, which stated that ToU tariff weekday peak consumption was 89% of consumption in the control group with nobody aged 16-64 in the household, 93% with one person and 97% with two people aged 16-64 in the household. As a result, the percentage peak demand reduction is not entirely comparable with the figures reported for other trials.

group. The EdF trial did not report the results of testing the ToU tariff for consumers without an IHD, so the incremental effect of enhanced information on demand shifting is not available.

- The SSE *EDRP trial* found that provision of an IHD or web information reduced consumer responsiveness to ToU signals. The authors suggest that this may be due to an "interference effect". They argue that too many interventions at once may have overloaded consumers.

54. **However, in most international trials, the provision of real-time information led to a small additional reduction in peak demand**.

- The *BGE Pricing Pilot* found a greater critical peak energy use reduction for consumers with Energy Orbs compared to those without. Reductions of 23-27% were found for consumers with Energy Orbs, while those without reduced their demand by 18-21%[73].

- The *Integral Energy Trial* found that electricity use during critical peaks was reduced by 37% for CPP tariff consumers without an IHD. Providing an IHD increased the reduction to 41%.

- In the *Ireland Electricity Smart Metering Trials* 91% of consumers with an IHD found that this provided important support for achieving peak demand reduction, and 87% found that it provided important support for shifting to off-peak night rates.

- In the *OG&E Trial,*[74] consumers on a ToU tariff with an IHD reduced their demand by 17% compared to 11% for those on the same tariff with web information on prices and recent consumption only.

55. However, some trials found real-time information to be less effective.

- The *CL&P Pilot*, found no additional peak load reductions for consumers on ToU, CPP and CPR tariffs given Energy Orbs or an IHD, compared to those on the same tariffs without these[75].

- Further, in the *OG&E Trial*, consumers on a CPP tariff with an IHD reduced their peak demand by 11%, compared to 12% for those with basic web information only.

56. It is not clear from the information presented in the studies why the impact of real-time information varies.

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73 Consumers in the sample were recruited sequentially into different tariff rates, and were not aware of the other tariffs available. It is not entirely clear whether the consumers were selected to receive additional measures such as Energy Orbs, or whether they were able to choose these. This finding conflicts with the findings on Energy Orbs of the CL&P trial.

74 Silver Spring Networks, 2011, SEDC: Consumer Engagement and Demand Response Case Study; and Raab Associates, 2011, OGE: Engaging Consumers for Demand Response.

75 Consumers in the sample were randomly selected into a tariff and technology option, and were not able to switch between these.

Key finding 4:
Consumer feedback on tariffs and interventions aimed at incentivising DSR was generally positive.

57. Some trials collected information on consumer perceptions of the trials. Feedback after the trials was generally positive. This held for trials looking at both regular day-in day-out responses and occasional critical peak responses.

- 92% of participants in the *CL&P Pilot* said they would participate in the pilot again, and overall satisfaction was on average rated 5.1 out of 6.

- 78% of 298 survey respondents from the *Ontario Smart Price Pilot* said they would recommend the ToU tariff to a friend. The top 3 reasons given for satisfaction were:

    - awareness of how to reduce bill;
    - greater control over electricity costs; and
    - environmental benefits.

- 74% of participants said they were satisfied with the *PowerCents DC Trial*. 89% of participants would recommend the trial to a friend. Further, more than 93% of participants that responded stated a preference for PowerCents DC pricing structures over the default, which was a rising block tariff (a fairly common tariff in the US).

- 77% - 81% of participants in the *myPower Trial*[76] said they would recommend myPower to a friend or relative.

58. In some cases, perceptions of the tariff types were more positive after the trials than before. Feedback from the *Ontario Smart Price Pilot* indicated that before the trial consumers had feared that the ToU tariff would be a ‘money grab,’ but after the trial they no longer perceived the tariff this way.

59. Survey evidence found that motivations for participation in the trial were mainly financial and environmental.

- In the *CL&P Pilot*, 86% of residential participants said they participated in the pilot to save money, while 67% listed the positive impact on the environment as a motivation for joining the pilot. Those that joined the pilot for environmental reasons were more satisfied than those that joined to save money.

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[76] Summit Blue Consulting, 2007, Final Report for the myPower Pricing Segments Evaluation.

- In the *Ontario Smart Price Pilot*, the main reasons consumers gave for participating in the pilot were that they wanted to be prepared for the arrival of ToU pricing, they liked the idea of being able to monitor their electricity use and they felt this would give them more control over their electricity bills.

- In the *PowerCents DC Trial*, the top motivations for participation were saving money (73%), reducing emissions (34%), exploring smart grids (33%), and assisting policymakers (32%).

- The majority of participants in the *myPower Trial* believed the scheme benefited the environment, and 71% of participants believed they saved money on the programme.

Impact on bills

60. **Consumers tended to save money on the trials.** This was often because trials were designed to be revenue neutral for the average consumer who does not change their demand patterns[77]. This meant that when consumers did respond to the economic incentives in the tariffs by shifting consumption to cheaper periods, they saved money on their bills. In addition, some trials included additional backstop measures to ensure that no individual consumer lost out financially by taking part[78].

- On average, consumers on the *Ontario Smart Price Pilot* saved 3% compared to the non-ToU bill.

- 88% of consumers on *PG&E's SmartRate programme* had lower bills during the trial. The average saving for SmartRate consumers between May and October was 8.2%. The average saving for consumers on PG&E's ToU tariff was 18% over a year.

- Participants in the *PowerCentsDC trial* made savings of 2% (CPP tariff consumers), 5% (CPR tariff consumers), and 39% (real-time pricing consumers) relative to the standard tariff. 91% of CPP and CPR tariff consumers saved money, and all real-time pricing consumers made savings.

- 86% of participants with automating technology and 71% of participants without experienced lower bills in the *myPower* trial. Average savings were higher for consumers who were provided with automating technology than for those that were not. However, survey results of *myPower* participants showed that, for consumers with and without automating technology, average reported savings were less than consumers had expected.

- As discussed in more detail in paragraph 83, savings made by some consumers may be passive: savings may be achieved without behaviour change if the consumer was already consuming less than average at peak times. This was the case for the consumers in the *Northern Ireland Powershift trial*.

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77 For a trial intervention to be revenue neutral for the average consumer, the bill of the average consumer must be the same under the trial tariff as under the standard offering, if that consumer does not change their demand patterns during the trial.

78 Some trials (for example the Ireland Electricity Smart Metering Trials and the Ontario Smart Pilot) guaranteed that individual consumers would not face higher bills as a result of participating in trials by providing them with an adjusted subsidy payment at the end of the trial period.

- There was one exception to this pattern. Although 55% of consumers on *PSE's ToU trial*[79] had lower bills during the first year of the tariff, in the second year 94% paid an extra $0.80 per month after PSE introduced a monthly meter reading fee. Consumer dissatisfaction and negative press coverage led to the tariff being withdrawn.

[79] Faruqui and George, 2003, Demise of PSE's ToU Program imparts lessons.

Part 2 - Areas where evidence from the trials is inconclusive

61. We have identified five important areas where the evidence remains inconclusive:

- There is little evidence on the reasons for differing responses of vulnerable or low-income consumers to DSR measures.
- Testing of real-time pricing for households has not produced robust results to date.
- Evidence on the impact of non-economic signals alone is mixed.
- There is limited evidence available on which electricity use consumers shift in response to incentives. For example, with the exception of air-conditioning and storage heating, it is not clear which appliances consumers are willing to use in a flexible way.
- There is limited evidence available on whether DSR persists over time, if it is not automated or directly controlled.

62. In this section the evidence relating to these areas is reviewed.

Vulnerable and low-income consumers

63. The Government's Fuel Poverty Strategy[80] defines vulnerable consumers as people with a long-term illness, families with children, disabled people and the elderly. No trials were found which looked specifically at these groups. However, some evidence was found on the impact of DSR measures for large households (which are likely to correspond to families with children)[81]. Consumers defined as vulnerable in the Government's Fuel Poverty Strategy will not necessarily have low-incomes. However results for low-income consumers are also of interest, and are included in this section.

Large households

64. The evidence on the impact of DSR measures on large households is mixed.

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80 Vulnerable consumers are defined in the UK Fuel Poverty Strategy 2001 as people with a long-term illness, families with children, disabled people and the elderly, http://www.decc.gov.uk/assets/decc/what%20we%20do/supporting%20consumers/addressing%20fuel%20poverty/strategy/file16495.pdf.

81 By large households we mean households with multiple occupants. We are not referring to the size of the property itself. The definition of large households varied between trials. For example, the UK Energy Demand Research Project defined small households as those with one or two adults between the ages of 16 and 64, and the California State-Wide Pilot compared two and four person households.

- The *California State-Wide Pricing Pilot*[82] found that smaller households were more responsive to price changes than larger households.

- Similarly the EdF *EDRP trial* found that households with one or two people aged 16-64 reduced their peak demand more than larger households.

65. It is not possible to find a conclusive explanation for this based on the evidence presented in the studies. However, the following factors may contribute.

- The household member that enrolled in the trial may be more aware of the incentives supplied to encourage DSR than other household members. This awareness may be diluted as the number of additional household members increases.

- Larger households may on average have different requirements for electricity which affect the amount of load that they can shift. For example, households with children may have less flexibility to reduce demand during peak hours. There is some evidence for this from the *Ontario Smart Price Pilot*. In this study, some families with small children reported that they found it difficult to reduce laundry use during peak periods.

66. In contrast, the *Ireland Electricity Smart Metering Trials* found that households with children under the age of 15 reduced their peak demand by more than the average (10.7% compared to 6.5%). Focus group evidence suggested that this was due to the effects of educational initiatives in schools in Ireland, which may result in children driving behaviour change in their household.[83]

Low-income consumers

67. Evidence from the US on the impact on low-income consumers of interventions to encourage DSR is mixed. Studies have looked at the impact on bills for low-income consumers, the response of low-income consumers to economic incentives, and their response to non-economic incentives.

Bills

68. **US studies have found that the impact of ToU or CPP tariffs on bills for low-income consumers is likely to be positive**. The *Institute for Electric Efficiency (IEE) Whitepaper "The Impact of Dynamic Pricing on Low Income Customers" (2010)* notes that flatter initial loads for low-income consumers (that is, electricity use that is spread more evenly across the day) mean that, before any behaviour change, low-income consumers may see a reduction in bills in a move from a flat rate tariff to a ToU or a CPP tariff. This is because, compared to the average consumer, low-income consumers already consume a higher proportion of their electricity at off peak times, when prices are

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82 Charles River Associates, 2005, Impact Evaluation of the California State-wide Pricing Pilot.

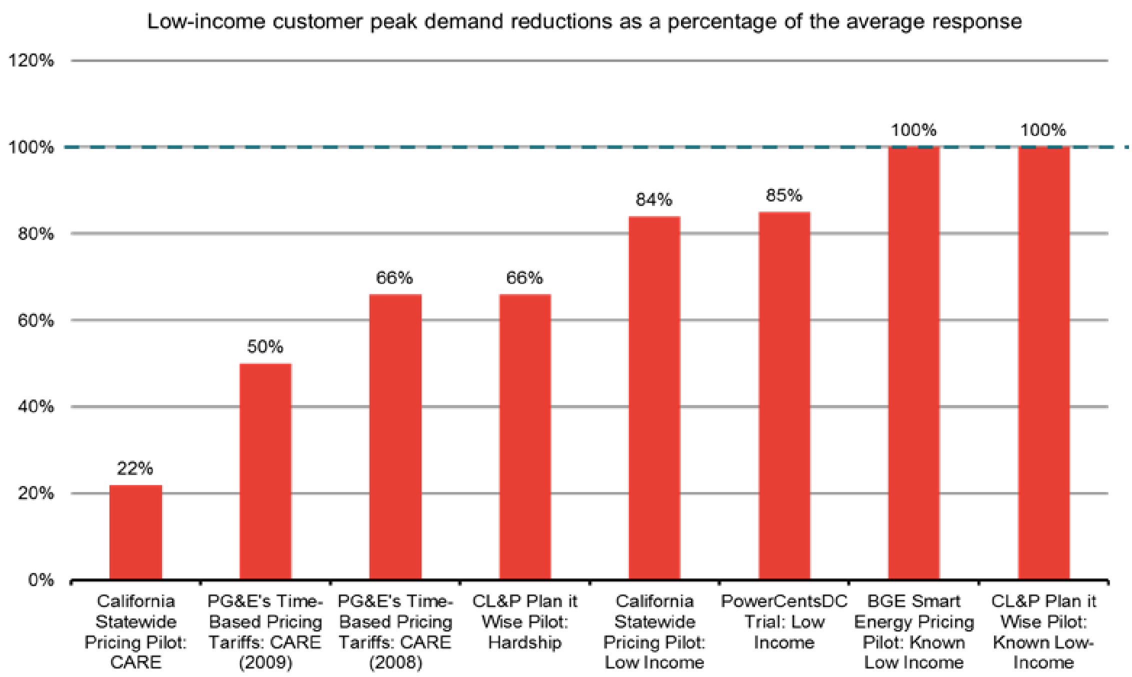
83 The Findings Report for the Irish trials provided the example of An Taisce's Green Schools programme: Commission for Energy Regulation, 2011, Electricity Smart Metering Customer Behaviour Trials (CBT) Findings Report and its appendices

lower under ToU or CPP tariffs. In addition, Faruqui and Palmer[84] simulated the impact on electricity bills of CPP tariffs and found that 65% of low-income consumers were immediately better off on the CPP rate than they would be on a flat tariff, before any behaviour change.

Response to economic incentives

Evidence on responsiveness to economic incentives by income group in the UK is limited, and further research would be required before UK-specific conclusions could be drawn in this area. International studies covered in the IEE Whitepaper generally found that **low-income consumers in the US do respond to incentives to shift load, but that their responses tend to be smaller than the responses for average consumers**. However, the evidence is mixed as some trials found that demand response by low-income consumers did not differ from the response by non-low-income consumers. This is illustrated in Figure 2 below. The definitions used for low-income varied between the studies, for example using self-reported low-income status, or eligibility for US "CARE" (a discount on electricity bills which depends on household income and size).

Figure 2: Low-income consumer peak demand reductions in the US



Source: This is adapted from Figure 1 in the US study "The Impact of Dynamic Pricing on Low Income Customers" (IEE Whitepaper, 2010).

69. US studies have found a number of possible reasons why low-income consumers have different peak use reductions relative to non-low-income consumers.

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84 Faruqui and Palmer, 2011, Dynamic Pricing and Its Discontents, Regulation, Vol. 34, No. 3, p. 16, Fall 2011. Available at SSRN: http://ssrn.com/abstract=1956020

- *Lower overall electricity use.* Demand reductions (at peak and other times) may be lower for low-income consumers if their overall electricity use is below average. Lower overall electricity use may mean these consumers have less discretionary load than an average consumer, and this may limit the extent to which they can reduce demand at any time of day (including peaks). There is evidence that on average low-income households have lower electricity consumption than high income households in the UK[85]. Therefore it is plausible that they may have less discretionary load to shift in response to incentives, although this has not been tested.

- *Flatter load shapes*. The IEE Whitepaper finds that loads are flatter for low-income consumers in the US. This may be because these consumers are more likely to be at home during the daytime (for example due to being unemployed, retired or disabled). This corresponds to the findings of the *Northern Ireland Powershift trial*, in which consumers in the trial group, who mostly had low incomes, were found to benefit from the lower off-peak prices in the ToU tariff passively (that is, without having to change their behaviour), as a lot of their electricity use was already at off-peak times[86,87]. Flatter initial loads may reduce the scope of low-income consumers to shift demand from peak periods, as they are already consuming less in peak periods.

- *Other consumer characteristics*. Low-income consumers may have different standards of housing and different appliance ownership to average consumers. In one US-based study, the *PG&E Trial*, the difference between low-income and average consumers was fully accounted for by differences in appliances used by these groups. Under the SmartRate CPP tariff in this trial, results for CARE consumers did not significantly differ from results for other consumers once underlying characteristics such as possession of air conditioning units, language spoken by the household, whether notification of the critical peak had been successful and "other" factors were controlled for. It is clear that appliance use varies by income in the UK. For example, in Great Britain, use of peak electric heating is more prevalent amongst low-income than better off households. Of the 560,000 households in Great Britain whose primary heating source is peak electricity, 53% are in the bottom two income quintiles[88]. However, the effect of different appliance use by income on DSR has not been tested in the UK.

- *Smaller economic incentives.* If low-income consumers receive a discount on the price they pay for electricity, the impact of the price differential with a ToU or CPP tariff may be limited.

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85 A study by the Centre for Sustainable Energy (CSE) using UK Expenditure and Food Survey (EFS) data for 2004-2007 found that mean electricity consumption was lower for households in lower income deciles than in higher deciles. However, their analysis also found that there were 1.7 million low income households (defined as households with income below 60% of the median) with above average electricity consumption, out of 6,733,877 households in income poverty according to this measure. Centre for Sustainable Energy, 2010, Understanding 'High Use Low Income' Energy Consumers. Available at http://www.cse.org.uk/downloads/file/understanding_high_use_low_income_energy_consumers.pdf (Accessed 02/04/2012.

86 If a ToU tariff is set to be revenue neutral for the average consumer, consumers with a flatter than average demand profile will benefit from this tariff, even before they make any response. For a trial intervention to be revenue neutral for the average consumer, the bill of the average consumer must be the same under the trial tariff as under the standard offering, if that consumer does not change their demand patterns during the trial.

87 Owen and Ward, 2007, Smart meters in Great Britain: the next steps? Paper 6: Case studies.

88 Sustainability First GB Electricity Demand – realising the resource. Paper 3B What demand side services could household customers offer? Forthcoming. 2012 (Data from English, Welsh and Scottish housing surveys.)

This was found to affect CARE consumers in the *California State-Wide Pricing Pilot* and the *PG&E Trial*. In the *Ireland Electricity Smart Metering Trials*, households receiving the Free Electricity Allowance (the elderly, carers with specified allowances and individuals receiving specified disablement benefits), had weaker incentives to shift load due to the allowance they received. This group's peak electricity use fell less than the average consumer on ToU tariffs. It is not clear whether this would be the case in the UK[89].

- *Response to automation and information.* Results from the *OG&E Trial* showed that consumers responded differently to non-economic incentives according to their income. The provision of IHD or web portal access along with a CPP tariff had a smaller impact on percentage reductions from low-income consumers than for higher income consumers. In contrast when the CPP tariff was combined with a smart thermostat[90], which allows an automated response to tariff rates, peak demand reductions were higher for low-income than high-income consumers. This suggests that the type of non-economic measure that will be most effectively combined with dynamic ToU tariffs may vary according to household income. However, other factors which may be correlated with income, such as the age of participants, may also have driven this result.

Real-time pricing

70. With real-time pricing retail prices vary in line with wholesale cost movements. Tariffs may, for example, vary hourly based on day-ahead hourly wholesale electricity prices. We looked at four studies which test the impact of real-time pricing. These are summarised in Table 5.

Table 5: Summary details for the trials of real-time pricing

Trial	Country	Number of participants
Norway EFFLOCOM Trial (2001-2004)	Norway	81
PowerCentsDC Trial (2008-2009)	USA	231
Illinois Real-Time Pricing Trial (2003-2006)	USA	~1,500

89 Currently, the six largest energy suppliers in GB are required to offer a "warm home discount" to vulnerable consumers. The warm home discount provides a rebate (of £120 in 2011/12), which may have less of an impact on consumer incentives than a discount on the price per unit faced by consumers would have: DECC, 2011, Warm Home Discount Scheme: Winter 2011/12 Adviser Factsheet. Available at http://cfe.custhelp.com/ci/fattach/get/340/0/session/L2F2LzEvdGltZS8xMzMyOTI1ODM4L3NpZC84dHlBbWNVaw==/filename/DECC+WHD+Guidance+Sheet.pdf; and Consumer Focus, 2011, The Warm Home Discount, Available at http://cfe.custhelp.com/ci/fattach/get/339/0/session/L2F2LzEvdGltZS8xMzMyOTI1ODM4L3NpZC84dHlBbWNVaw==/filename/Consumer+Focus+briefing+on+the+Warm+Home+Discount.pdf (Accessed 28/03/2012).

90 A smart thermostat allows an automated response to real-time signals such as tariff periods or prices.

Trial	Country	Number of participants
Pacific NorthWest GridWise Project (2006-2007)	USA	112

71. **The limited available evidence suggests that domestic consumers do respond to real-time price signals**. There has been limited testing so far of domestic sector real-time pricing. Only four of the studies we looked at have involved this type of pricing.

- The *PowerCentsDC Trial* included an hourly pricing tariff for households where consumer prices were based on the day-ahead price in wholesale markets. Consumers were notified a day in advance by phone, email or text message if prices were going to exceed a high price threshold. Information on hourly prices was available in real-time on smart thermostats, online, and at a free telephone number. However, the results of this trial were inconclusive. Wholesale prices fell over the trial period. This made it difficult to separate out the demand shifting effect resulting from the pricing structure from changes in consumption resulting from the overall fall in price.

- The *Norway EFFLOCOM Trial*[91] also included tariffs that partially depended on the hourly wholesale electricity spot price[92]. This found larger peak demand reductions for consumers where the tariff depended on the spot price compared to those on the tariff that did not. However, the number of consumers with hourly variation in their prices was too small to provide statistically significant results.

- In the *Illinois Real-Time Pricing Trial*[93], domestic electricity prices were based on day-ahead wholesale prices. Consumers were notified the day before by phone or email when the price went above a threshold, and the overall hourly price was capped. Prices were available, after 5pm a day in advance, on the programme website or by phone. On the day with the highest price, consumers on real-time tariffs reduced their *overall* consumption by 15% compared to consumers on standard tariffs[94]. The trial also found that consumers' responsiveness was greatest when the electricity price was above the high price threshold.

- *The Pacific Northwest GridWise Project*[95] found that consumers respond less to real-time price signals than to ToU and CPP signals. During this trial, the domestic electricity price was

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91 EFFLOCOM Partners, 2004, Energy efficiency and load curve impacts of commercial development in competitive markets, Results from the EFFLOCOM Pilots.

92 The hourly spot price is the real-time wholesale price of electricity.

93 Summit Blue Consulting LLC, 2007, Evaluation of the 2006 Energy-Smart Pricing Plan, Final Report.

94 Jongejan, A., Katzman, B., Leahy, T., and Michelin, M., 2010, Dynamic Pricing Tariffs for DTE's Residential Electricity Customers.

95 Hammerstrom, 2007, Pacific Northwest GridWise Testbed Demonstration Projects, Part I. Olympic Peninsula Project.

adjusted every five minutes. The reduction in peak period demand for consumers on this tariff was 15-17%, compared to 20% for the group on ToU/CPP tariffs[96].

72. More information would be needed to be able to provide robust conclusions on how consumers engage with more complex tariffs such as real-time pricing, and how the outcomes compare with those achieved using other tariffs.

The impact of non-economic signals alone

73. In this section, we examine the evidence from the limited number of trials which relied only on non-economic signals, such as the provision of information.

74. We looked at five trials that examined the impact of providing non-economic signals alone. With the exception of the *EDRP*, these were aimed at reducing demand during critical peaks. **The evidence from these trials on whether non-economic signals alone can deliver DSR is mixed.**

- The *Flex Alert Campaign*[97] used mass media including TV and radio advertising and alerts on energy supplier websites to encourage consumers in California to reduce their electricity use during critical peak events. This campaign had some success, with 37% of all survey respondents reportedly taking conservation action in response to the Flex Alert message (whether the message was received via advertisements or through media coverage). However, there was some evidence that consumers found the campaign confusing. Two important areas of confusion raised by survey respondents for the *Flex Alert Campaign* were as follows.
    - Less than half of respondents who remembered receiving an energy conservation message understood that the demand reduction was required at certain times of day.
    - There was little understanding of how climate change and the generation of electricity were linked. This meant that advertisements mentioning both were poorly understood.
- The *California State-Wide Pricing Pilot* tested an information only plan that encouraged consumers to reduce demand on critical peak days. These consumers did not see any change in their tariffs, but were given educational material about how to reduce loads during peak periods. Suppliers notified them in advance, in the same way as critical peak pricing consumers, when critical days were called. This trial found that those consumers that took part in the information only campaign showed no statistically significant change in their peak demand.

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96 Faruqui and Sergici (The Brattle Group), 2009, Household Response to Dynamic Pricing of Electricity - A Survey of the Experimental Evidence.

97 Summit Blue Consulting, 2008, 2008 Flex Alert Campaign Evaluation Report.

- The *Energy Australia Trial* also tested the impact of only providing consumers with information on peak demand periods. The trial found that consumers did shift their electricity demand, although it is not reported by how much.

- The *EdF EDRP Trial* compared the impact of ToU tariffs to the impact of providing consumers with an IHD[98]. This trial found that the reduction in consumption was greater with a ToU tariff, with weekday peak consumption of 96% relative to consumers with an IHD display alone.

- An information campaign was also introduced in France, although no analysis of its effectiveness is available. Under the French programme, *EcoWatt*[99], on very cold days, consumers are alerted by text or email and asked to reduce their electricity demand. Nine alerts were sent during winter 2008/9 and the programme had over 30,500 subscribers by spring 2011.

Types of behaviour change during the trials

75. **There is limited evidence available on the electricity-using activities that consumers shift in response to incentives** – for example, on the specific appliances they choose to avoid using at peak time. The literature tends to report the overall reduction in peak demand achieved by the intervention but generally does not specify which electricity-using activities consumers have chosen to shift. The exception is for automated DSR. As discussed under Key Finding 2, with automation, a specific appliance, typically air conditioning, is programmed to provide an automated response.

76. Information on which activities consumers change in response to the DSR incentives was mainly collected by survey evidence. This means that the evidence may not fully reflect actual behaviour.

- The Electricity Policy Research Group (EPRG) survey[100] asked respondents in the UK about their willingness to delay appliance use by up to 2 hours to after 9pm if they were offered a discount for shifting their consumption. The survey results showed that willingness to shift time of use varied, depending on what they were using the electricity for. 92% of respondents watched TV between 7 and 9 pm, and 48% cooked. For both of these activities, willingness to shift use to after 9pm in response to an economic incentive was low (17% of respondents that watched TV and 1% of respondents that cooked said they would shift their activity). Consumers were more willing to shift their use of washing machines and dishwashers. However, the percentage of consumers using these appliances between 7 and 9pm was lower (28% for washing machines, 18% for dishwashers).

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98 They tested a "basic display". This was a mains connected real-time display which allowed consumers to view their electricity use, the cost of this use (current, daily, weekly and monthly), tariff rates, and CO2 emissions.

99 Réseau de transport d'électricité, 2011, Generation Adequacy Report, on the electricity supply-demand balance in France.

100 Platchkov, Pollitt, Reiner, and Shaorshadze, 2011, 2012 EPRG Public Opinion Survey: Policy Preferences and Energy Saving Measures. Available at http://www.econ.cam.ac.uk/dae/repec/cam/pdf/cwpe1149.pdf (Accessed 02/04/12)

- In the *PowerCentsDC Trial*, 60% of survey respondents said they avoided using appliances, 59% said they reduced air conditioning consumption, and 44% said they turned off lights to reduce peak demand.

- In the *Ontario Smart Price Pilot*, focus group respondents said they shifted their electricity use to off-peak times by changing the time of laundry and dishwashing and adjusting air conditioning or heating thermostats.

- When the *EdF Tempo Tariff*[101] was being trialled, the main demand reduction on peak days came from reduced use of electric heating[102]. Consumers either used fireplaces or accepted a lower temperature.

- In the *ETSA Utilities Trials*[103] in Australia, participants in the trial said they reduced air conditioning, computer and TV use during summer peak events.

Persistence of DSR interventions

77. As discussed under Key finding 1, most trials found that consumers do respond to economic incentives to shift demand. **However, there is limited evidence on whether this DSR persists over time if it is not automated or directly controlled**. Most trials in the literature were relatively short (up to a year in length), which prevents conclusions on persistence beyond one cooling or heating season being drawn. However, those trials which looked over a longer period generally found that behaviour change persisted.

- Peak load reductions did not decline over three years for a CPP tariff trialled on 25,500 consumers in *PG&E's* study.

- For the larger CPP tariff trial in the *California State-Wide Pricing Pilot*, there was no statistically significant difference in the size of demand reductions during critical peaks in the summers of 2003 and 2004.

- For the *Ireland Electricity Smart Metering Trials*, peak use reductions were higher in the second six months compared to the first six months of the trial. This suggests that demand shifting increased as consumers learnt more about the different tariff structures and how to reduce their peak electricity consumption.

- Results from the *BGE Pricing Pilot* showed that consumers became more responsive to the CPR tariff in the second year of the trial. This result also held for consumers with an Energy

101 EFFLOCOM Partners, 2004, Energy efficiency and load curve impacts of commercial development in competitive markets, Results from the EFFLOCOM Pilots.

102 The EdF Tempo tariff is a dynamic ToU tariff with a fixed number in any year of each of three different types of day. These are blue (normal), white (mid-peak) and red (high-peak), and the type of day is determined one day in advance. Both peak and off-peak prices are higher on red or white days than on blue days

103 ETSA Utilities, 2010, Demand Management Program Interim Report No. 3.

Orb and for those with an Energy Orb and air conditioning cycling switch[104]. Again, increased load shifting over time suggests that consumers learn how to benefit from DSR measures.

- However, for the small ToU trial in the *California State-Wide Pricing Pilot*, reductions in peak energy use were 5.9% for summer 2003, and 0.6% for the same period in 2004. While this suggests a decrease in consumer engagement over time, the paper stresses that the sample size was small (although it was large enough for the results to be statistically significant).
- Consumers in the *California automated demand response trial*[105] had lower average peak period demand reductions in the second year of the trial than in the first year. This trial tested a CPP tariff alongside an enabling technology which allowed appliances such as central air conditioning units to be automated.

104 Faruqui and Palmer, Dynamic Pricing and Its Discontents, 2011, Regulation, Vol. 34, No. 3, p. 16, Fall 2011. Available at SSRN: http://ssrn.com/abstract=1956020

105 Rocky Mountain Institute, 2006, Automated Demand Response System Pilot, Final Report.

Part 3 - DSR in other sectors

78. Lessons about the most effective ways of encouraging DSR from domestic electricity consumers can also be learned from other sectors. We have looked at three sectors:

- rail;
- domestic water sector; and
- telecoms.

79. We chose these three sectors for the following reasons.

- As with demand for electricity, demand for rail and telecoms services is subject to daily peaks and services cannot be 'stored'. Therefore sufficient capacity must be in place to supply peak demand. DSR to shift demand within days can reduce costs by reducing the need for investment in new capacity.
- Water demand is similar to electricity demand in that much of it is not discretionary, for example, water used for hygiene and cooking. While water itself is easier to store than electricity, there are significant energy costs associated with the supply of water. DSR to encourage within-day shifting of water demand to minimise related energy costs has been trialled in the US.

80. For each of these sectors, we looked at the extent to which measures are in place to encourage consumers to shift demand away from peak and how consumers responded to these measures.

Key findings from other sectors

81. **As in the domestic electricity sector, consumers in the water, telecoms and rail sectors do respond to both economic and non-economic signals by shifting demand away from peak.** This result is consistent with Key Finding 1 for electricity demand, and therefore seems to be a consistent theme in sectors where there are network constraints.

82. There was insufficient evidence on DSR in other sectors to test the applicability of Key Findings 2-4. However a number of other useful insights can be gained from these sectors:

Rail sector

- **Design of DSR incentives should consider the price charged in the 'shoulder' period adjacent to the peak period, as well as the price charged in the peak period itself**. The shoulder period is the period that occurs directly before and after the evening peak period. If the price in the shoulder period is too low, new demand peaks may be created when incentives to move demand away from the peak period are applied. This consideration is likely to be important for electricity DSR, given that some electricity end-uses may only be delayed for relatively short periods only.

Telecoms sector

- **Evidence from the telecoms sector suggests that the consumer response to DSR signals differs according to the time of day.** This finding may be transferable to domestic electricity demand, given that appliance use varies between morning and evening peaks.

Water sector

- One study found that consumers shifted their water consumption by time of day in response to economic incentives and that the new demand patterns persisted even after the economic incentive was removed[106]. There is little evidence on persistence from electricity sector studies, so it is not clear how applicable this finding is to domestic electricity DSR.

We now present a more detailed discussion of each of the sectors.

Rail

83. There are some similarities between the demand for rail travel and demand for electricity. In passenger rail transport there are predictable peaks in hourly demand and supply costs can be reduced by smoothing these peaks[107]. There is little discretion around the time of some demand (for example many commuter journeys) but more discretion around the time of other demand (such as some leisure travel).

84. There is substantial experience of using price signals to provide an incentive to move demand in the rail sector, with different fares applying at different times. However, published evidence on the responsiveness of consumers to such economic incentives is relatively limited. The following insights can be drawn.

- **Large price differentials during both the peak period, and the adjacent 'shoulder' periods are required to change passenger behaviour.**

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106 Although results about what water demand was moved were not available, the authors strongly suspect it is outdoor watering [that was curtailed]. House, L.W. (Water Consulting) for Public Interest Energy Research, California Energy Commission, 2011, Time-of-use Water Meter Effects on Customer Water Use, p. 34

107 The Rail Value for Money Study, commissioned by DfT and ORR (McNulty, 2011) found that current fare structures in the UK do not provide a financial incentive to switch away from travelling at the high-peak hour. The government's response stated that smoothing demand within the 7-10am and 4-7pm periods on commuter routes could delay the need for investment in infrastructure and new trains, as the existing capacity would be used more efficiently. Evidence in the Initial Consultation on rail fares and ticketing showed that there was spare capacity on commuter services to London, Birmingham and Leeds on either side of the high peak.

- Research by Faber Maunsell[108]modelled hypothetical passenger responses to ToU fare variation for three different routes. It found that, to change passenger behaviour, a combination of increased capacity, surcharges for travel at peak times, and reductions in shoulder peak fares would be required.
- Steer Davies Gleave[109] built on the Faber Maunsell model. It found that an increase of up to 40% in the peak fare and up to 20% in the fare that applied for the 60 minute periods before and after the peak period would be required to reduce high peak half hour demand to the level of demand during the adjacent shoulder peak half hours.

- **There is some evidence that consumers find the large range of different fares confusing.**
  - Research by the consumer organisation Which? suggested that some consumers had a low understanding of the three main types of ticket in the UK. For example, only 49% of rail passengers surveyed knew that off-peak tickets could be used on any train outside peak hours.

Telecoms

85. The telecoms sector uses incentives to move the time of demand, with differential prices across the day used for some voice calls. Shifting demand within the day is also relevant for mobile data, as networks can experience congestion at peak times. Relevant insights from studies of the effects of time of day pricing in the telecoms sector are as follows:

- A number of studies found that consumers do respond to changes in time of day pricing by changing the time when they make calls. Many of these investigated whether consumers are more responsive to price changes at certain times of the day.
  - Chen and Watters (1992) used data on long-distance calls from Southwestern Bell Telephone Company and found that consumers in the US were more sensitive to price changes for daytime calls than for evening, night or weekend calls.
  - Dotecon (2001) found that consumer responsiveness was highest for calls during the evening period and lowest during the daytime for fixed line to mobile calls. This study included business consumers as well as domestic consumers and the result may have been driven by the fact that business callers are less sensitive to price signals and are more likely to make calls during the daytime.

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108 "Demand Management Techniques – Peak Spreading," for the Department for Transport, Transport for London and Network Rail. Results reported on pages 52-53 of the Research Project on Fares by Steer Davies Gleave.

109 Steer Davies Gleave, 2011, Research Project on Fares, Final Report: analysis, recommendations and conclusions.

- A study by Chen and Watters (1992) reported in Gillen (1994) found that consumers were more likely to switch from daytime to off-peak (evening or night/weekend) periods than they were to switch between evening and weekend periods.
- Dotecon (2001) found no evidence that consumers shifted daytime calls to evenings in response to relative price changes although there was little variation in this study in the relative price between the daytime and evenings.

- Experimental evidence on time-dependent pricing in a trial by Princeton University[110] for mobile data showed that consumers respond to economic signals combined with real-time price notifications.
    - The trial found that during high price periods, the average percentage fall in internet use was 10.1% for iPads and 11.3% for iPhones. Between 80%- 90% of users reduced their use after receiving the first high-price notification.
    - The experiment targeted price notifications at consumers whose demand was above a certain threshold. Notifications were sent at ten minute periods, so a consumer who did not reduce their demand below the threshold would receive multiple notifications during the high-price period.

Domestic water

86. Water can be stored more easily than electricity, so there is little direct benefit to shifting domestic water demand within the day. Most demand side initiatives have therefore been based on reducing seasonal or annual demand rather than shifting it away from daily peak periods. However there are benefits to reducing the electricity use associated with water pumping during the daily electricity demand peaks. Relevant insights from demand reduction and DSR trials in the water sector are as follows:

- **One US study found that consumers respond to economic incentives to shift their water demand away from peak times[111].**
    - One study in California trialled a $25 per month economic incentive for domestic consumers to reduce their water demand during the summer peak electricity demand period. The trial aimed to test water smart meters and to investigate whether providing an incentive to move water demand within the day would have a knock on effect on the peak electricity demand associated with pumping water. The study found that peak period water demand fell by more than 50% for domestic consumers with the economic incentive, compared to a control group. Reductions in peak period water demand by residential consumers persisted in the month after

110 Princeton University experiment, Experimental Evaluation of Time Dependent Pricing for Mobile Data.

111 We also found critical peak pricing and direct control programmes for electric irrigation. These were directed at reducing peak electricity use by electric irrigation, rather than shifting the time of day at which water was used. However, they were not directed at domestic consumers so we do not review the results here.

the economic incentive was removed, indicating that consumers formed new habits as a result of the study.

- **Economic and non-economic incentives can be effective in providing an incentive to consumers to reduce demand, though the results vary across different uses.**

    - A literature review by Olmstead and Stavins (2007) estimated an average price elasticity of urban residential water demand in the US of between -0.3 and -0.4. They also found that moving from a non-metered tariff to a flat metered tariff reduced water use by 20% on average.

    - Olmstead and Stavins (2007) reviewed a range of studies looking at the effects on water demand of non-price demand reduction initiatives. The reductions in water demand varied widely, from zero to large and statistically significant changes.

    - A review of the literature by Cole (2011) found that overall demand for water was less responsive to changes in price in winter than summer, and for indoor compared to outdoor use. This was because outdoor use was perceived as discretionary, so was more responsive to price changes.

    - Olmstead and Stavins (2007) also found that consumers may adjust their behaviour to maintain comfort, leading to a 'rebound' effect after demand saving devices are installed. For example, if consumers were given low-flow showers, they may then take longer showers, counteracting the demand reduction from the initial installation.

- **Bespoke targeting of high users has been used in the water sector.**

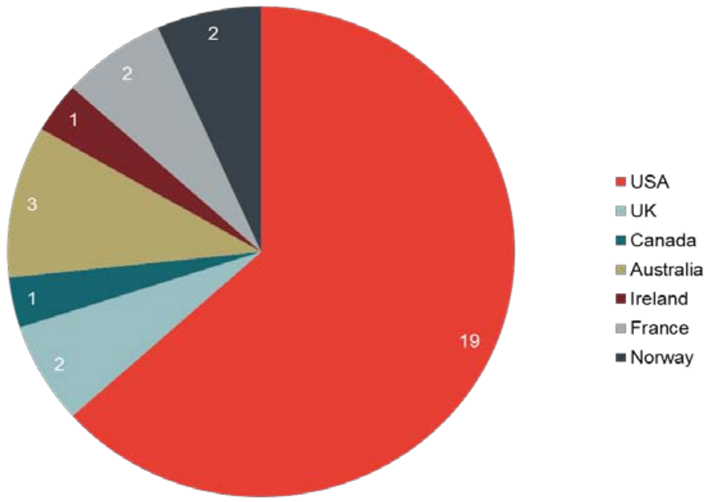
    - The Modesto Irrigation District and the City of Modesto targeted high-use consumers. High-use consumers were given assistance to detect leaks, advice on how to use water more efficiently, and help to set sprinkler timers. The effectiveness of these measures was not reported in the study. However, it is plausible that targeting higher users could be more cost-effective as higher users may have more discretionary load.

Part 4: Conclusions and further research

Conclusions for the UK

87. Most of the trials covered in this review were undertaken outside the UK-see below (Figure 3).

Figure 3: Number of trials by country



88. This section first describes evidence directly from the UK. It then looks at the factors which may impact on the applicability of the international findings to the UK.

Evidence from the UK

89. Evidence from the UK is based on the *EDRP* and the Northern Irish *Powershift* trials, and on the experience of the long-running Economy 7 tariff[112].

- **Evidence on consumer response to ToU tariffs in the UK is mixed.**
  - A shift in demand away from peak was observed in the *Powershift* trials, though it is not clear whether the result was statistically significant.
  - In the case of the EdF *EDRP* trial, only households with fewer than three occupants responded to the ToU tariff by reducing their peak demand.

112 No published analysis of the impact of Economy 7 tariffs on consumer behaviour was found. However, the fact that many consumers have allowed their heating appliances to be automated under this tariff for many years provides evidence of the acceptability of this kind of intervention in the UK. We highlight research into Economy 7 tariffs as an area for further work in the next section of this report.

  - In the SSE *EDRP* trial a small response was observed.

- **There is also UK evidence that consumers are willing to accept a degree of automation of their load.** Many Economy 7 consumers in the UK already allow remote controlling of electric storage heaters and some automation of hot water.

- **UK evidence on the impact of additional information runs counter to that found in other studies.** The SSE trial within the *EDRP trials* found that the provision of an IHD and web information reduced the responsiveness of consumers to economic incentives.

- Sustainability First analysis of evidence from the 200 household *Powershift* trial suggests that **low-income consumers in Northern Ireland tend to have a different mix of appliances than consumers with average incomes**, which may affect their ability to shift demand. For example, low-income consumers tend to have higher levels of electric heating without storage. This lack of storage may make it more difficult for them to shift demand.

90. It is clear that evidence from the UK is relatively sparse compared to evidence from North America. European evidence, including from the comprehensive and well-designed *Ireland Electricity Smart Metering* may be applicable to the UK to a greater degree. However significant research gaps remain. We set out our view of further research priorities in this area for the UK in the next section of this report.

Applicability of international findings to the UK

91. Differences in local conditions across trials are likely to impact on the applicability of findings to the UK. In particular, differences across the following categories may be important.

- **Appliance stock.** The appliances consumers use will impact on the proportion of consumers' load which is flexible. Much household electricity load may be relatively inflexible, for example the load associated with lighting, cooking and consumer electronics such as televisions. There may be greater flexibility, or potential for automation, associated with particular appliances, such as air conditioning or electric heating. Climate and cultural factors mean air conditioning penetration varies significantly across countries. Electric heating penetration also varies across countries, driven by factors such as availability of other fuels for household heat, including oil and gas. Penetration levels of electric heating and air conditioning among domestic consumers are currently low in the UK.

- **Housing stock**. For example, better insulated homes may facilitate greater flexibility with appliances for heating and cooling.

- **Cultural factors.** For example, in some countries, consumers may already be used to having their electricity load controlled during peak periods. The use of consumer appliances such as televisions and IT equipment may also differ between countries due to cultural factors.

- **Economic conditions.** Differences between average incomes and average energy prices may affect the sensitivity of consumers to a given price signal. When economic conditions are difficult, for example during a recession, people may be more motivated by the desire to save money.

92. Little information is available within the trial literature on these specific local characteristics (with the exception of the appliance stock, discussed below). However with the exception of the results for CPP and CPR tariffs, each of our key messages is supported by evidence from a range of countries.

93. One area where locally specific information is available is around the appliance stock: it is clear from the literature that many of the trials were carried out in regions with higher penetrations of air conditioners than currently found in the UK.

94. Air conditioning demand has two important characteristics in this context:

- it is associated with a significant load (around 4 kW[113] in a domestic property compared to average domestic peak demand of less than 2kW in the UK)[114]; and
- it is potentially flexible and open to automatic control as thermostats can be adjusted for short periods during peak times without significantly affecting comfort levels.

95. While air conditioning penetration is currently low in the UK, the move to a low-carbon economy over the next decades is likely to involve an increase in the penetration of electric heat pumps and electric vehicles. The per unit load of these technologies will be of a similar magnitude to the load associated with air conditioners, and the demand associated with them is likely to have some flexibility.

96. The limited available evidence suggests that users of electric vehicles may be content to charge their vehicles overnight rather than at peak periods[115] but heat pump demand may have similar characteristics to air conditioning demand. Little is known so far about the characteristics of heat pump demand, since rollout has not yet been widespread. However heat pumps are similar to air conditioners in two ways: they are based on similar technology and the extent to which demand is flexible depends on the degree to which consumers are willing to accept a small decrease in comfort during peak periods. Therefore some insights from trials featuring air conditioners may be applicable to heat pump use in the UK. Recent papers from the Sustainability First GB Electricity Demand project explore some of these end-use and flexibility issues.[116]

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113 Crossley, D. (Energy Futures Australia), 2010, International Best Practice In Using Energy Efficiency and Demand Management to Support Electricity Networks.

114 Sustainability First estimate that peak demand is 0.9 kW for consumers whose meters do not distinguish between the time of day (approximately 22 million consumers), and 1.9kW for consumers with separate peak and off-peak meters (approximately 5 million consumers) in the UK. Sustainability First, 2012. These estimates are for winter (December-March). Average daily demand peaks are below 0.6kW for both groups of consumers from June-August.

115 For example, the Mini E trial found that nine out of ten participants found that overnight charging suited their routine. This trial of electric vehicles featured "special night-time tariffs, successfully encouraging individual drivers to charge when it was cheapest". https://www.press.bmwgroup.com/pressclub/p/gb/pressDetail.html?outputChannelId=8&id=T0118820EN_GB&left_menu_item=node__2310

116 Sustainability First, 2012, GB Electricity Demand - 2010 and 2025. Initial Brattle Electricity Demand-Side Model - Scope for Demand Reduction and Flexible Response.

Further research

97. We have identified a number of areas where further research into domestic DSR is likely to be important.

98. In the near term, there are five areas in particular where further research could increase our understanding of the potential role for domestic DSR in the UK.

- **DSR and low income and vulnerable consumers in the UK**. There is little UK-based evidence on low income consumers and DSR and no trials have looked specifically at vulnerable consumers, as defined by the DECC Fuel Poverty Strategy[117]. To ensure that measures to provide incentives for DSR do not have negative impacts on vulnerable groups, further research focussing on elderly consumers, consumers with children, and the long term ill or disabled will be important.

- **Consumer behaviour and attitudes in relation to the Economy 7 tariff**. Between 3-3.5m consumers are already on the ToU Economy 7 tariff in Great Britain[118] and the electric storage heating of some of these consumers is automated. Analysis of the behaviour of consumers on Economy 7 tariffs, for example analysis of how their use of appliances other than heating compares to consumers on flat rate tariffs, could provide very useful insights.

- **Persistence of DSR.** Little research has focussed on the persistence of DSR over time. Understanding more about what might drive the persistence of responses over the long term will be important to ensure that investment is focussed on DSR measures which can provide a sustainable response.

- **Appliance use and behaviour patterns**. The Household Electricity Survey provides data on electricity end use at appliance level and yield insights into behavioural patterns, for example by showing which appliances are typically used during peak periods.[119][120] These data could provide a basis for further work aimed at understanding more about the flexibility of consumer demand associated with each appliance.

- **Response to price differentials**. There is little evidence from the UK on whether consumers' responses to price signals differ according to the strength of the price signal. Further research in this area would be useful.

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117 Vulnerable consumers are defined in the UK Fuel Poverty Strategy 2001 as people with a long-term illness, families with children, disabled people and the elderly:
http://www.decc.gov.uk/assets/decc/what%20we%20do/supporting%20consumers/addressing%20fuel%20poverty/strategy/file16495.pdf

118 Sustainability First, 2012.

119 DECC/Defra/EST, 2012, Household Electricity Survey:
http://randd.defra.gov.uk/Document.aspx?Document=10043_R66141HouseholdElectricitySurveyFinalReportissue4.pdf

- **Response to non-economic signals alone.** Findings on the response of consumers to non-economic signals alone vary across trials. Further research in this area may be useful.

99. The importance of DSR to the future electricity system is driven to a large degree by the need to move to a low-carbon economy. It is therefore crucial that future research focusses on consumers that use low-carbon demand-side technologies, and on measures which are likely to help manage a generation system dominated by low-carbon generation supply. This research could focus on the following areas.

- **Impact of electrification of heat and transport on DSR.** Published evidence on the flexibility of the new demand-side technologies associated with the move to a low-carbon economy is not yet available. It is generally considered likely that low-carbon technologies will increase the flexibility of demand, however this has not yet been verified through trials, either in the UK or internationally. While some lessons can be drawn from trials carried out on consumers with air-conditioning, trials focussing specifically on heat pumps (with and without storage) and on electric vehicles would provide very useful information.

- **Testing of dynamic pricing and load control.** Wind generation is expected to make a substantial contribution to generation in the UK, contributing more than a quarter of generation by 2020.The benefits of dynamic pricing and load control are likely to greatly increase as the penetration of intermittent generation technologies, such as wind, increases. Research in this area has been limited to date, and further research in the UK context would be very useful.

100. Finally, we note that important trials in some of these areas are already being planned or carried out with funding from the Technology Strategy Board, the Energy Technology Institute and Ofgem's Low Carbon Network Fund. Investment in **the regular collation and dissemination of the results from the ongoing trials will be extremely important**. This could help ensure that the results from the trials feed into both ongoing trial design and, ultimately, into policy development.

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Annexe A: Summary details for each set of trials

Figure 4: Peak period demand reductions and peak to off-peak price differentials under ToU tariffs

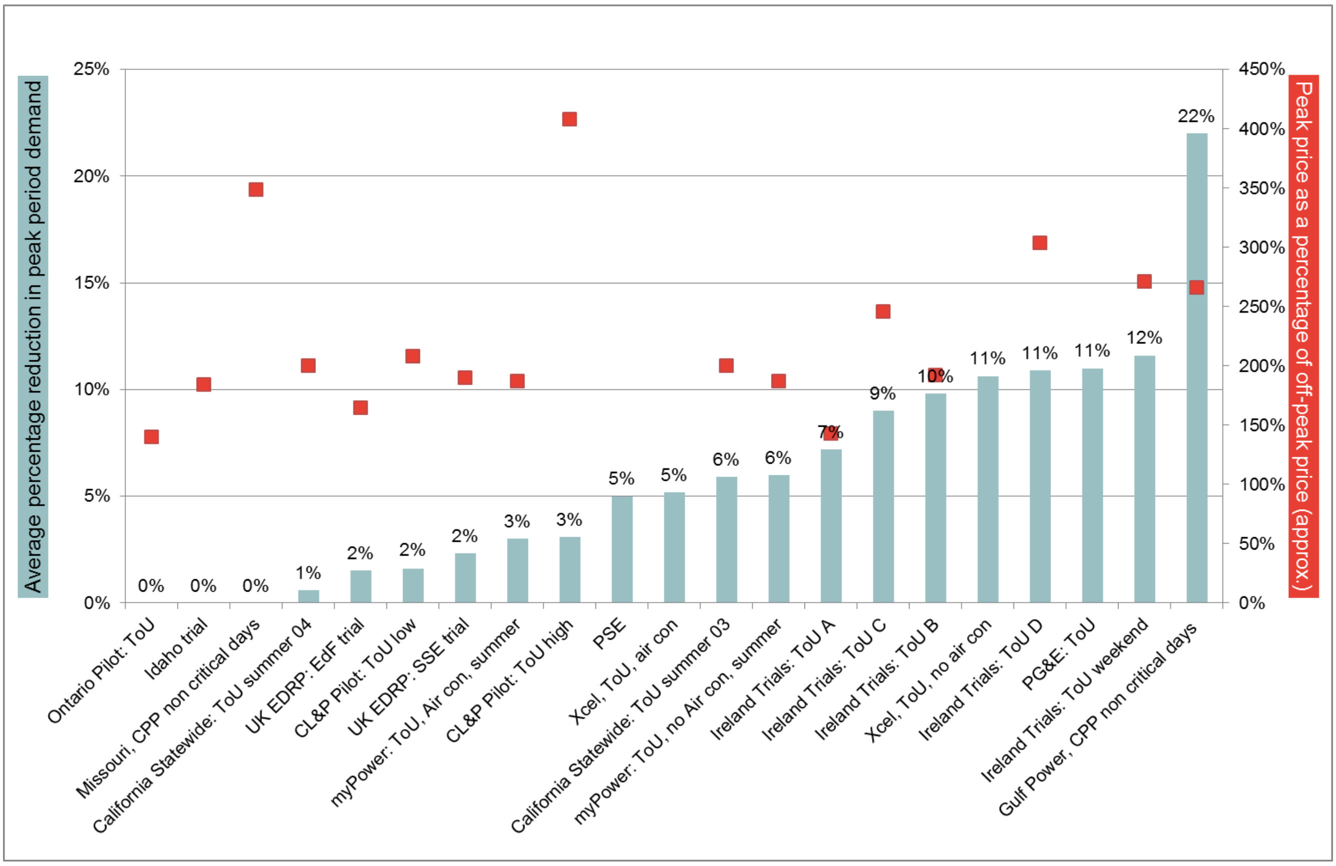


Figure 5: Critical peak period demand reductions and critical peak to off-peak price differentials under Critical Peak Pricing tariffs

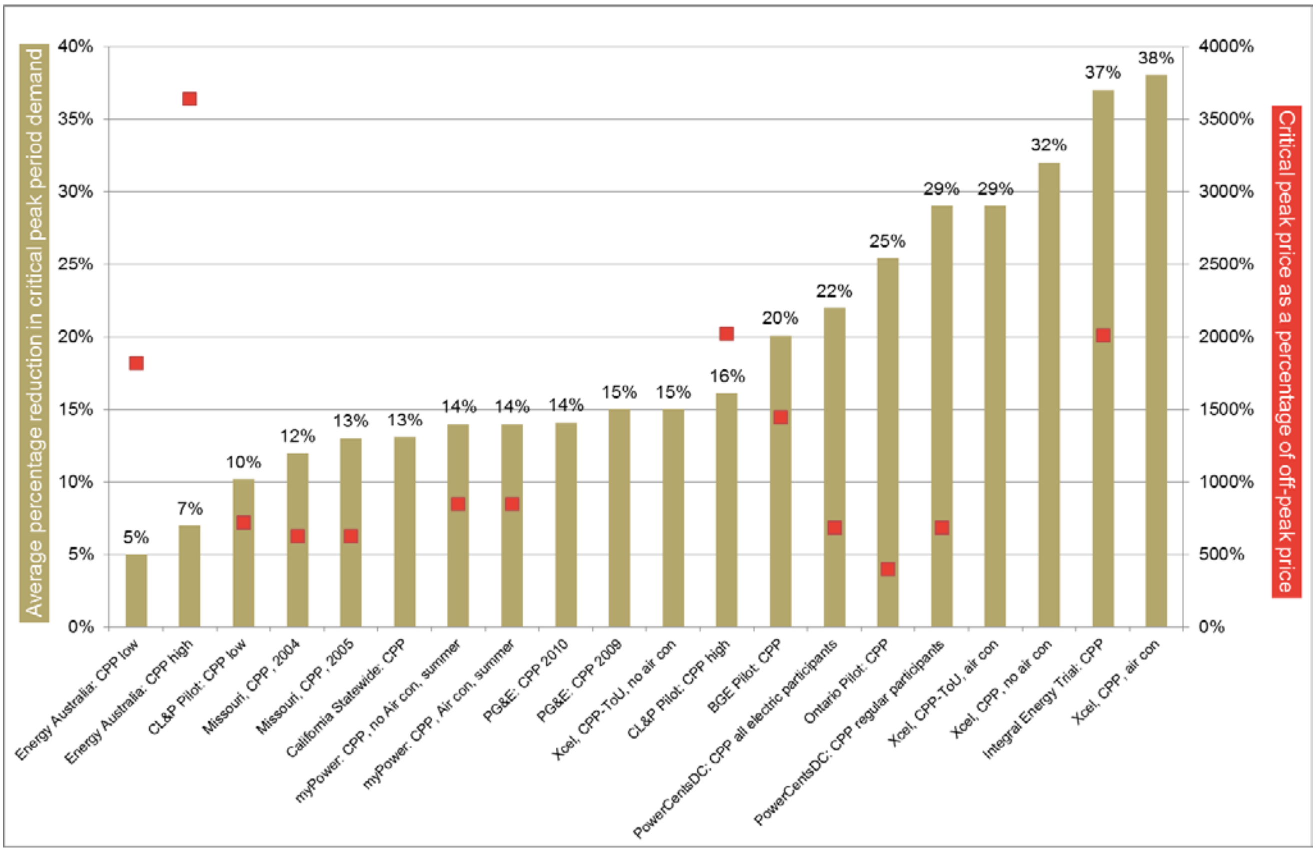


Figure 6: Critical peak period demand reductions and critical peak rebate to off-peak price differentials under Critical Peak Rebate tariffs

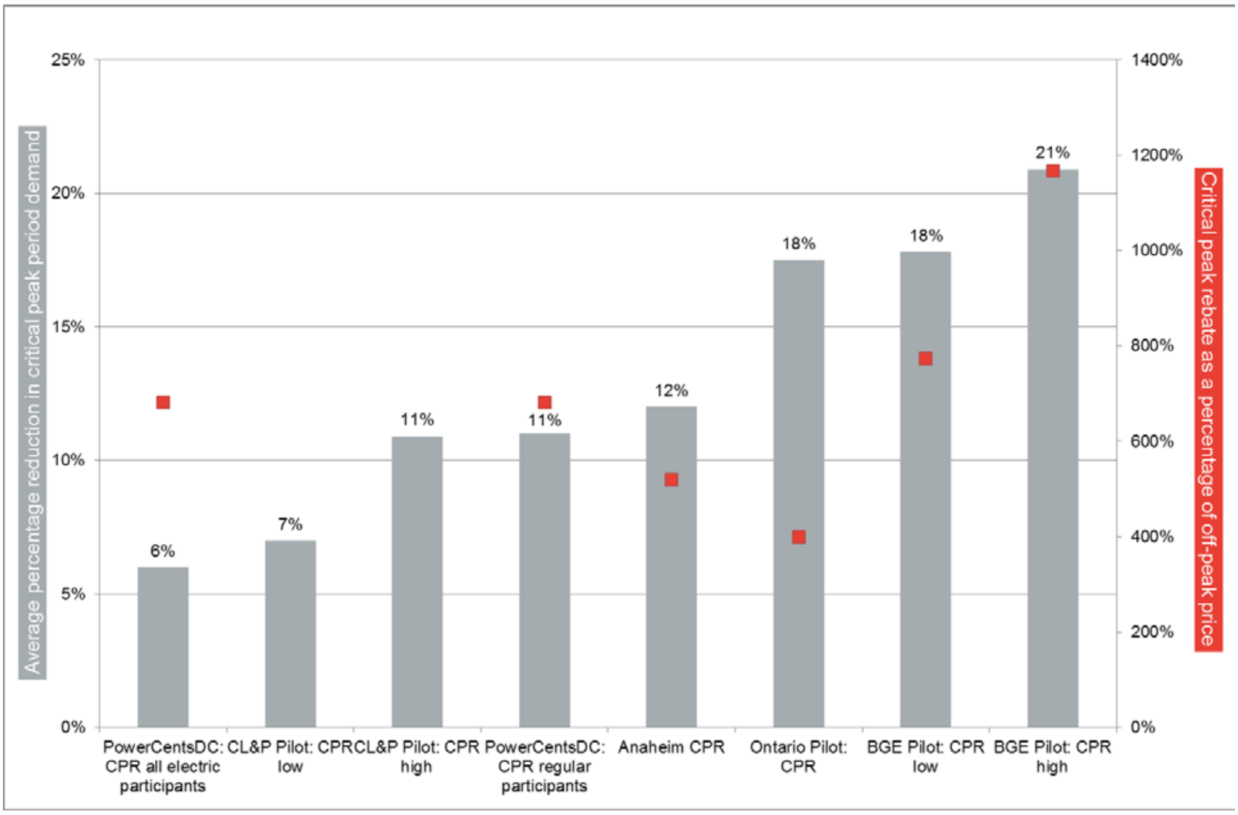


Figure 7: Comparison of demand reductions under CPR and CPP tariffs

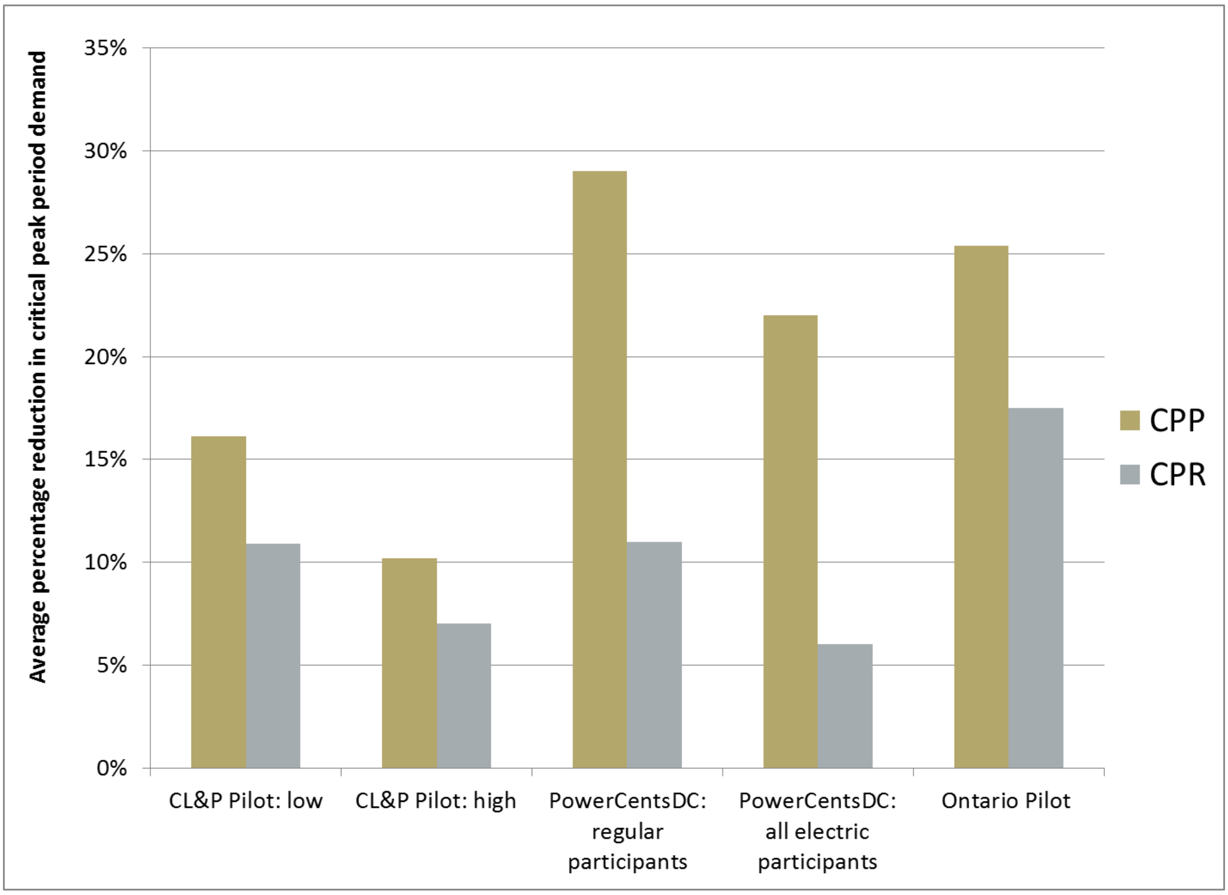
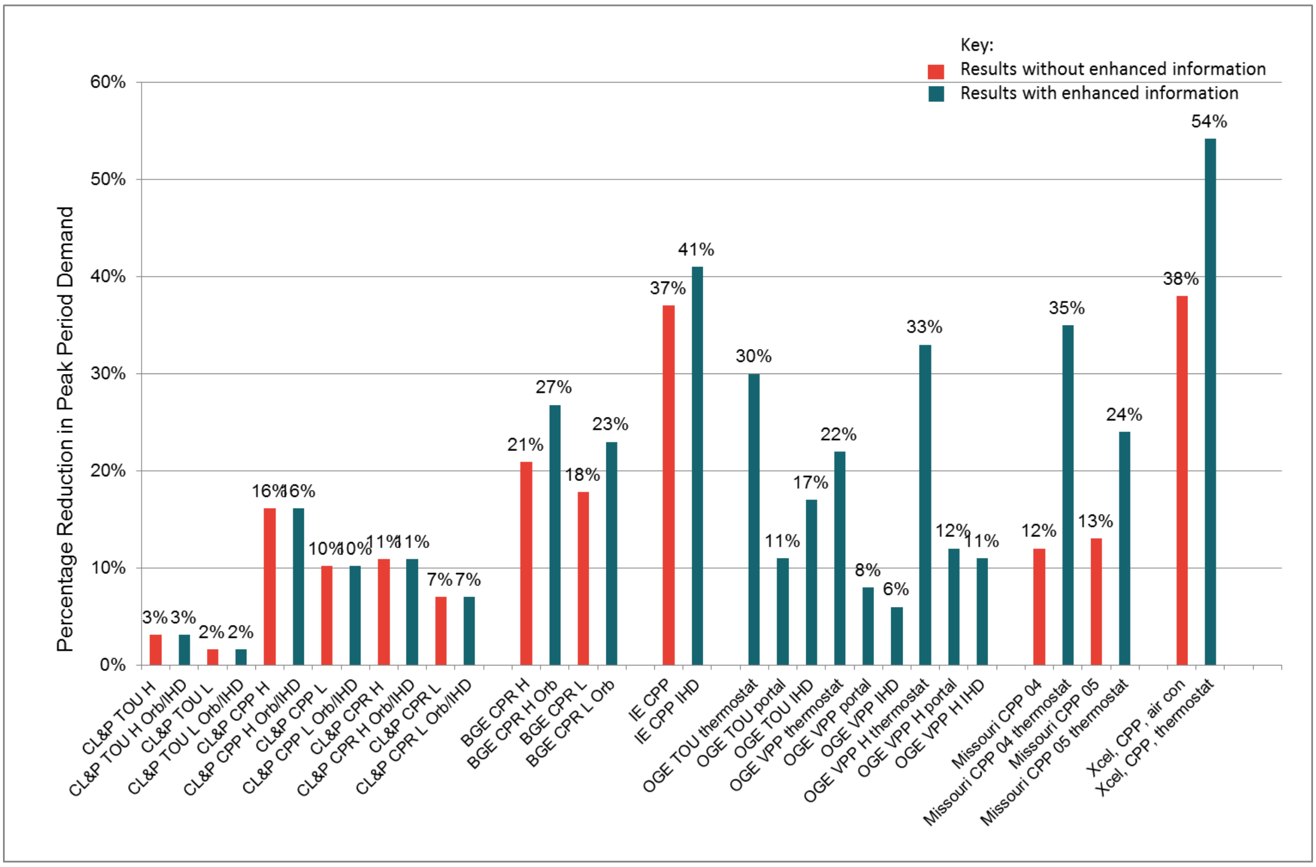


Figure 8: Comparison of peak period demand reductions with and without enhanced information



Annexe B: References for domestic electricity sector

AECOM Ltd for Ofgem, 2011, EDRP Final Analysis, Appendix D: SSE Community Trials. Available at http://www.ofgem.gov.uk/Sustainability/EDRP/Documents1/EDRP%20Appendix%20D%20SSE%20community%20trials.pdf (Accessed 24/01/2012)

AECOM Ltd for Ofgem, 2011, Energy Demand Research Project: Final Analysis. Available at http://www.ofgem.gov.uk/Sustainability/EDRP/Documents1/Energy%20Demand%20Research%20Project%20Final%20Analysis.pdf (Accessed 24/01/2012)

Centre for Sustainable Energy, 2010, Understanding 'High Use Low Income' Energy Consumers. Available at http://www.cse.org.uk/downloads/file/understanding_high_use_low_income_energy_consumers.pdf (Accessed 02/04/2012)

Charles River Associates, 2005, Impact Evaluation of the California State-wide Pricing Pilot. Available at http://sites.energetics.com/MADRI/toolbox/pdfs/pricing/cra_2005_impact_eval_ca_pricing_pilot.pdf. (Accessed 24/01/12)

Commission for Energy Regulation, 2011, Electricity Smart Metering Customer Behaviour Trials (CBT) Findings Report. Available at http://www.cer.ie/en/information-centre-reports-and-publications.aspx?article=5dd4bce4-ebd8-475e-b78d-da24e4ff7339&mode=author. (Accessed 24/01/12)

Commission for Energy Regulation, 2011, Electricity Smart Metering Customer Behaviour Trials (CBT) Findings Report Appendices, Available at http://www.cer.ie/en/information-centre-reports-and-publications.aspx?article=5dd4bce4-ebd8-475e-b78d-da24e4ff7339&mode=author. (Accessed 24/01/12)

Connecticut Light and Power, 2009, Appendices. Available at http://www.cl-p.com/Home/SaveEnergy/Plan-it_Wise_Pilot_Results_Appendix/. (Accessed 24/01/12)

Connecticut Light and Power, 2009, Results of CL&P Plan-It Wise Energy Pilot. Available at http://www.cl-p.com/Home/SaveEnergy/Plan-it_Wise_Pilot_Results/. (Accessed 24/01/12)

Consumer Focus, 2011, Getting to Grips With Smart Displays, An Expert Appraisal of the Usability of In-Home Energy Displays. Available at http://www.consumerfocus.org.uk/files/2011/08/Getting-to-grips-with-smart-displays.pdf. (Accessed 24/01/12)

Crossley, D. (Energy Futures Australia), 2010, International Best Practice In Using Energy Efficiency and Demand Management to Support Electricity Networks. Available at http://www.efa.com.au/Library/David/Published%20Reports/2010/InternationalBestPracticeinEEandDSMforNetworkSupport.pdf. (Accessed 24/01/12)

Department for Energy and Climate Change (DECC), 2011, Digest of United Kingdom Energy Statistics (DUKES). Available at http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx. (Accessed 09/03/12)

EFFLOCOM Partners, 2004, Energy efficiency and load curve impacts of commercial development in competitive markets, Results from the EFFLOCOM Pilots. Available at http://www.sintef.no/project/Efflocom/EFFLOCOM%20report%20no.%207%20Pilot%20Results%5b1%5d.pdf. (Accessed 24/01/2012)

eMeter Strategic Consulting, 2010, PowerCentsDC Program Final Report. Available at http://www.powercentsdc.org/ESC%2010-09-08%20PCDC%20Final%20Report%20-%20FINAL.pdf. (Accessed 24/01/12)

Energy Market Consulting Associates, 2009, Smart Meter Consumer Impact: Initial Analysis. Available at http://www.ret.gov.au/Documents/mce/_documents/smart_meters/Smart%20meter%20consumer%20impact%20analysis%20-%20EMCa%20report.pdf. (Accessed 24/01/12)

ETSA Utilities, 2010, Demand Management Program Interim Report No. 3. Available at www.etsautilities.com.au/public/download.jsp?id=11891. (Accessed 24/01/12)

Farrell, M., 2011*, OGE: Engaging Consumers for Demand Response. Available at* http://www.raabassociates.org/main/roundtable.asp?sel=109*. (Accessed 01/02/2012)*

Faruqui, A. and George, S., 2003, Demise of PSE's ToU Program Imparts Lessons, Electric Light & Power Vol. 81.01:14-15, Available at http://www.elp.com/index/display/article-display/165800/articles/electric-light-power/volume-81/issue-1/features/demise-of-pses-tou-program-imparts-lessons.html (Accessed 13/04/2012)

Faruqui, A. and Palmer, J., 2012, The Discovery of Price Responsiveness- A Survey of Experiments involving Dynamic Pricing of Electricity, unpublished paper submitted to the EDI Quarterly.

Faruqui, A. and Sergici, S. (The Brattle Group), 2009, BGE's Smart Energy Pricing Pilot, Summer 2008 Impact Evaluation. Available at http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/BGEPilots_SEP_Summer_2008_Report_%2805_05_09%29.pdf. (Accessed 24/01/12)

Faruqui, A. and Sergici, S. (The Brattle Group), 2009, Household Response to Dynamic Pricing of Electricity- A Survey of the Experimental Evidence. Available at http://www.hks.harvard.edu/hepg/Papers/2009/The%20Power%20of%20Experimentation%20_01-11-09_.pdf (Accessed 06/03/12)

Faruqui, A. and Palmer, J., 2011, Dynamic Pricing and Its Discontents, Regulation, Vol. 34, No. 3, p. 16, Fall 2011. Available at SSRN: http://ssrn.com/abstract=1956020

Freeman, Sullivan & Co., 2011, 2010 Load Impact Evaluation of Pacific Gas and Electric Company's Time-Based Pricing Tariffs, Final Report. Available at http://www.fscgroup.com/news/pge-2010-residential-pricing-programs-evaluation.pdf. (Accessed 24/01/12)

Freeman, Sullivan & Co., 2011, Southern California Edison's 2010 Demand Response Load Impact Evaluations Portfolio Summary. Available at http://fscgroup.com/reports/SCE-DR-Portfolio-Summary-2010.pdf. (Accessed 24/01/12)

Grande, O. and Sæle, H., 2011, Demand Response from Household Customers: Experiences from a Pilot Study in Norway, IBEE Transactions on Smart Grid, Volume 2, No. 1, pp.102-109.

Hammerstrom, D.J., 2007, Pacific Northwest GridWise Testbed Demonstration Projects, Part I. Olympic Peninsula Project. Available at http://www2.econ.iastate.edu/tesfatsi/OlympicPeninsulaProject.FinalReport_pnnl17167.pdf (Accessed 13/04/2012)

IBM Global Business Services and eMeter Strategic Consulting, 2007, Ontario Energy Board Smart Price Pilot Final Report. Available at http://www.oeb.gov.on.ca/documents/cases/EB-2004-0205/smartpricepilot/OSPP%20Final%20Report%20-%20Final070726.pdf. (Accessed 24/01/12).

Idaho Power, 2008, 2007 Energy Watch and Time-of-Day Programs Annual Report, Available at http://sites.energetics.com/MADRI/toolbox/pdfs/pricing/idaho_power_ami_pilots.pdf (Accessed 13/04/2012)

Institute for Electric Efficiency, 2010, The Impact of Dynamic Pricing on Low Income Customers. Available at http://www.edisonfoundation.net/iee/reports/IEE_LowIncomeDynamicPricing_0910.pdf. (Accessed 24/01/12)

Jongejan, A., Katzman, B., Leahy, T., and Michelin, M., 2010, Dynamic Pricing Tariffs for DTE's Residential Electricity Customers. Available at http://css.snre.umich.edu/css_doc/CSS10-04.pdf (Accessed 06/03/12)

Levy Associates, Principal Investigator, R. Levy and Plexus Research, Inc, Project Investigators, R. Abbott and S. Hadden, 2002, New Principles for Demand Response Planning, Electric Power Research Institute (EPRI). EP-P6035/C3047.

Mert, W., Suschek-Berger, J., and Tritthart, W., 2008, Consumer acceptance of smart appliances, D 5.5 of WP5 report from Smart-A project, A report prepared as part of the EIE project "Smart Domestic Appliances in Sustainable Energy Systems (Smart-A)." Available at http://www.smart-a.org/WP5_5_Consumer_acceptance_18_12_08.pdf (Accessed 06/03/12)

Owen, G. and Ward, J., 2007, Smart meters in Great Britain: the next steps? Paper 6: Case studies. Available at http://www.sustainabilityfirst.org.uk/docs/2007/Smart%20Meters%20in%20Great%20Britain%20-%20Paper%206%20-%20Case%20Studies%20-%20Sustainability%20First%20-%20July%202007.pdf (Accessed 24/01/12)

Owen, G. and Ward, J., 2010, Smart Tariffs and Household Demand Response for Great Britain. Available at http://www.sustainabilityfirst.org.uk/docs/2010/Sustainability%20First%20-%20Smart%20Tariffs%20and%20Household%20Demand%20Response%20for%20Great%20Britain%20-%20Final%20-%20March%202010.pdf (Accessed 24/01/12)

Platchkov, L., Pollitt, M.G., Reiner, D., and Shaorshadze, I., 2011, 2012 EPRG Public Opinion Survey: Policy Preferences and Energy Saving Measures. Available at http://www.econ.cam.ac.uk/dae/repec/cam/pdf/cwpe1149.pdf (Accessed 02/04/12)

Raab Associates, 2011, OGE: Engaging Consumers for Demand Response. Available at www.raabassociates.org/.../Farrell%20Presentation_10.28.11.pptx. *(Accessed 24/01/12)*

Réseau de transport d'électricité, 2011, Generation Adequacy Report, on the electricity supply-demand balance in France. Available at http://clients.rte-france.com/htm/an/mediatheque/telecharge/generation_adequacy_report_2011.pdf. (Accessed 01/02/12)

RLW Analytics for Corporate Planning AmerenUE, 2004, AmerenUE Residential ToU Pilot Study, Load Research Analysis First Look Results, Available at http://www.ontarioenergyboard.ca/documents/cases/RP-2004-0203/2005-07- (Accessed 13/04/2012)

RLW Analytics for Corporate Planning AmerenUE, 2006, Ameren UE Residential ToU Pilot Study, Load Research Analysis - 2005 Program Results, Available at http://sites.energetics.com/MADRI/toolbox/pdfs/pricing/res_tou_pilot.pdf (Accessed 13/04/2012)

Rocky Mountain Institute, 2006, Automated Demand Response System Pilot, Final Report, Available at http://sites.energetics.com/MADRI/toolbox/pdfs/pricing/ca_automated_dr_sys.pdf (Accessed 16/04/2012)

Silver Spring Networks, 2011, SEDC: Consumer Engagement and Demand Response Case Study. Available at http://sedc-coalition.eu/wp-content/uploads/2011/10/SilverSpringsConsumerEngagementandDRCaseStudy.pdf. (Accessed 01/02/12)

Summit Blue Consulting LLC, 2007, Evaluation of the 2006 Energy-Smart Pricing Plan, Final Report. Available at www.cntenergy.org/download/19/ (Accessed 24/01/2012)

Summit Blue Consulting, 2007, Final Report for the myPower Pricing Segments Evaluation. Available at http://sites.energetics.com/madri/toolbox/pdfs/pricing/mypower_pricing_final_report_2007.pdf. (Accessed 24/01/12)

Summit Blue Consulting, 2008, 2008 Flex Alert Campaign Evaluation Report. Available at http://www.calmac.org/publications/2008_Flex_Alert_Final_Report_12-18-08.pdf. (Accessed 24/01/12)

Summit Blue Consulting, 2009, Impact Evaluation of OPower SMUD Pilot Study, Available at http://opower.com/uploads/library/file/13/summit_blue_june_2009.pdf. (Accessed 24/01/12)

Summit Blue/ Navigant Consulting, 2010, Evaluation of Consumer Behavioural Research, Final Report. Available at http://www.nwcouncil.org/energy/neet/workgroups/4/Consumer%20Behavioral%20Research%20Report%20-%20Summit%20Blue.pdf. (Accessed 24/01/12)

Sustainability First and Engage Consulting Limited, 2008, International Smart Meter Trials, Selected Case Studies, Smart Tariffs and Customer Stimuli.http://www.sustainabilityfirst.org.uk/docs/2008/Sustainability%20First%20&%20Engage%20Consulting%20-%20International%20Trials%20-%20Tariffs%20and%20Consumer%20Stimuli%20-%20Selected%20Case%20Studies%20-%20May%202008.pdf (Accessed 24/01/12)

Sustainability First, 2012, GB Electricity Demand Project - Paper 2: GB Electricity Demand 2010 and 2025 – Initial Brattle Electricity Demand-Side Model: scope for demand reduction and flexible response. Available at http://www.sustainabilityfirst.org.uk/docs/2011/Sustainability%20First%20-%20GB%20Electricity%20Demand%20Project%20-%20Paper%202%20-%20GB%20Electricity%20Demand%202010%20and%202025%20-%20Initial%20Brattle%20Electricity%20Demand-Side%20Model%20-%20February%202012.pdf (Accessed 02/04/12)

Sustainability First, 2012, GB Electricity Demand Project - Paper 3: What demand-side services could GB customers offer?

University of California Energy Institute, Center for the Study of Energy Markets, 2002, Appendix B. Gulf Power's Residential Service Variable Price Option, Paper CSEMWP105. Available at http://sites.energetics.com/MADRI/toolbox/pdfs/vision/dynamic_pricing.pdf (Accessed 16/04/2012)

Vaasa-ett, 2011, The Potential of Smart Meter Enabled Programs to Increase Energy and Systems Efficiency: A Mass Pilot Comparison; Short name: Empower Demand. Available at http://www.esmig.eu/press/filestor/empower-demand-report.pdf. (Accessed 24/01/12)

Whitmarsh, L., Upham, P., Poortinga, W., Darnton, A., Devine-Wright, P., Demski, C., and Sherry-Brennan, F., 2011, Public Attitudes, Understanding, and Engagement in relation to Low-Carbon Energy: A selective review of academic and non-academic literatures. Report for RCUK Energy Programme. Available at http://www.ukerc.ac.uk/support/tiki-read_article.php?articleId=1188. (Accessed 27/01/2012)

Wolak, F.A., 2006, Residential Customer Response to Real-Time Pricing: The Anaheim Critical-Peak Pricing Experiment, Available at http://www.stanford.edu/group/fwolak/cgi-bin/sites/default/files/files/Residential%20Customer%20Response%20to%20Real-Time%20Pricing%2C%20The%20Anaheim%20Critical-Peak%20Pricing%20Experiment_May%202006_Wolak.pdf (Accessed 16/04/2012)

Annexe C: References for other sectors

Rail

Department of Transport and Office of Rail Regulation, 2011, Realising the Potential of GB Rail, Final Independent Report of the Rail Value for Money Study, Detailed Report. Available at http://assets.dft.gov.uk/publications/report-of-the-rail-vfm-study/realising-the-potential-of-gb-rail.pdf. (Accessed 09/02/12)

Kroes, M., Mitrani, A., Steer Davies Gleave, Weesie, L., Reizigers, Hofker, F., ProRail, 2009, The Impact of Tariff Differentiation on the Time of Day Choice and Rail Demand in the Netherlands. Available at http://etcproceedings.org/paper/the-impact-of-tariff-differentiation-on-time-of-day-choice-and-railway-demand- (Accessed 16/02/12)

Steer Davies Gleave, 2011, Research Project on Fares, Final Report: analysis, recommendations and conclusions. Available at http://www.railwaysarchive.co.uk/documents/rvfm-sdg-fares-280211.pdf. (Accessed 09/02/12)

Which?, 2011, Many people don't understand train tickets, Rail ticket websites add to confusion. Available at http://www.which.co.uk/news/2011/09/many-people-dont-understand-train-tickets-265963/. (Accessed 16/02/12)

Department for Transport, 2012, Rail Fares and Ticketing Review: Initial Consultation. Available at http://assets.dft.gov.uk/consultations/dft-2012-09/main-document.pdf (Accessed 20/03/12)

Department for Transport, 2012, Reforming our Railways: Putting the Customer First. Available at http://assets.dft.gov.uk/publications/reforming-our-railways/reforming-our-railways.pdf (Accessed 20/03/12)

McNulty, R., for the Department for Transport and the Office of Rail Regulation, 2011, Realising the Potential of GB Rail, Report of the Rail Value for Money Study, Summary Report. Available at http://www.rail-reg.gov.uk/upload/pdf/rail-vfm-summary-report-may11.pdf (Accessed 20/03/12)

Telecoms

Dotecon for BT, 2001, Estimation of Fixed to Mobile Price Elasticities. Available at http://www.dotecon.com/publications/elastftm.pdf (Accessed 06/03/12)

Gillen, D., 1994, "Peak Pricing Strategies in Transportation, Utilities, and Telecommunications, Lessons for Road Pricing;" in Curbing Gridlock, Peak-Period Fees to Relieve Traffic Congestion, Volume 2, Transportation Research Board Special Report 242, By the Transportation Research Board, Commission on Behavioral and Social Sciences and Education, National Research Council (U.S.)

Princeton University experiment, Experimental Evaluation of Time Dependent Pricing for Mobile Data. Available at http://scenic.princeton.edu/paper/TR_trial.pdf (Accessed 06/03/12)

Water

Cole, G., 2011, Time of use tariffs: reforming the economics of urban water supply. Available at http://www.nwc.gov.au/__data/assets/pdf_file/0008/17999/63-Time_of_use_tariffs.pdf (Accessed 15/02/12)

House, L.W. (Water and Energy Consulting) for Public Interest Energy Research (PIER) California Energy Commission, 2011, Time-of-use Water Meter Effects on Customer Water Use. Available at www.waterandenergyconsulting.com/touwater.pdf (Accessed 06/03/12)

House, L.W. (Water and Energy Consulting) for Public Interest Energy Research (PIER) California Energy Commission, 2010, Smart Meters and California Water Agencies: Overview and Status. Available at http://www.waterandenergyconsulting.com/smartmeterfinal.pdf (Accessed 06/03/12)

Joint 2010 Urban Water Management Plan, 2010, City of Modesto & Modesto Irrigation District. Available at http://www.mid.org/water/uwmp/2010_final_modesto-MID_UWMP.pdf (Accessed 15/02/12)

Olmstead, S., and Stavins, R., 2007, Managing Water Demand, Price vs. Non-Price Conservation Programs. Available at http://www.hks.harvard.edu/fs/rstavins/Monographs_&_Reports/Pioneer_Olmstead_Stavins_Water.pdf (Accessed 15/02/12)

Sharp, L., 2006, Water Demand Management in England and Wales: Constructions of the Domestic Water User, Journal of Environmental Planning and Management, Vol. 49, No.6 869-889. Available at http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=6484c9c8-03c9-496e-9646-f50302278896%40sessionmgr11&vid=2&hid=107 (Accessed 15/02/12)

Wide Bay Water Corporation, Innovative Smart Metering Program for Hervey Bay, Fact Sheet. Available at http://www.widebaywater.qld.gov.au/CMS/Uploads/file/smartmeters_mono.pdf (Accessed 15/02/12)

Annexe D: Summary of studies

Table 6. BGE Smart Energy Pricing Pilot (2008)

Overview	Content and purpose
Title of study:	BGE's Smart Energy Pricing Pilot, Summer 2008 Impact Evaluation
Author(s):	Ahmad Faruqui and Sanem Sergici
Date:	April 28, 2009
Source:	http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/BGEPilots_SEP_Summer_2008_Report_%2805_05_09%29.pdf
Categorisation	
Country/region:	Baltimore, USA
Period covered:	June 1 2008-September 30 2008
Sample size:	1375 residential consumers (of which 354 consumers constituted a control group).
Consumer categorisation:	-
DSR categorisation:	The following pricing structures were tested. • Dynamic peak pricing; • Peak time rebate with a low rebate level; and • Peak time rebate with a high rebate level. These schemes were overlaid on a two-period time-of-use (ToU) tariff. Twelve critical peaks were called during the period, and each lasted for the duration of the usual daily peak period. Consumers were notified about the critical peak a day in advance.
Incentives for	All consumers (including the control group) received $25 upon completion of an appliance survey half-way through the pilot,

Overview	Content and purpose
participation	and consumers on the tariffs being trialled received $25 for completing a survey at the end of the programme. For dynamic peak pricing consumers, non-critical-peak rates were adjusted in order to make the scheme revenue neutral. See Tables 2.1-2.2 in the paper for rates.
Other relevant features:	-
Information and enabling technologies:	If the consumer did not already have a meter that could record electricity usage in 15 minute intervals, then this was installed. Some consumers received an in-home display (an "Energy Orb," which displayed different colours to signal off-peak, peak and critical-peak hours). Some consumers (all of whom had received the Energy Orb) also received a switch for cycling central air conditioners. The energy supplier (Baltimore Gas & Electric Company, BGE) used this switch to reduce typical air conditioning usage by 50% during critical peaks for these consumers. Consumers were able to access information about the relevant pricing programme online. Rebate consumers received a savings report after critical peak events that outlined their savings during the programme overall, and for the past critical event. Critical peak pricing consumers received a monthly savings report.
Consumer take up of DSR tariffs/schemes	-
Summary of results	
Assumptions:	-
Implications for key questions	
What behaviours changed?	Load reductions during critical peaks ranged between 18% and 33% (significant at the 5% level). With the Energy Orb, load reductions were 23%-27%. With the Energy Orb and central air conditioner switch, load reductions were 29%-33%. The elasticity of substitution for the critical peak pricing and critical peak rebate schemes were not found to be significantly different. On non-critical days, load reductions were 1.8% for dynamic peak pricing alone, and 4.4% where dynamic peak pricing, and

Overview	Content and purpose
	the Energy Orb and air conditioner switch were used.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	Housing/appliances: Central air conditioning ownership did not significantly affect substitution away from critical peak electricity usage.
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	Peak period demand reductions were higher for consumers with Energy Orbs and air conditioner switches: • 33% for consumers on the CPP tariff compared to 20% for consumers without Energy Orbs or air conditioner cycling switches. • 33% for the high CPR rate, compared to 27% for consumers on the same rate with Energy Orbs only. • 29% for the low CPR rate, compared to 23% for consumers on the same rate with Energy Orbs only.
Did different consumers behave differently?	The elasticity of substitution away from electricity usage on critical peak days was: • lower for multi-family home residences; • higher for those with a college education or higher; • higher for those with a pool; and • higher for those with income above $75k. These figures were partially based on survey evidence. 20% of consumers did not respond to the survey, so these figures are not for the full sample.

Overview	Content and purpose
Are the results consistent over time?	The trial ran for one summer only.

Table 7. California State-wide Pricing Pilot (2003-2004)

Overview	
Title of study:	Impact Evaluation of the California State-wide Pricing Pilot
Author(s):	Charles River Associates
Date:	March 16 2005
Source:	http://sites.energetics.com/MADRI/toolbox/pdfs/pricing/cra_2005_impact_eval_ca_pricing_pilot.pdf
Categorisation	
Country/region:	California, USA Participants were drawn from four climate zones. 48% of the population lived in zone 2, 30% in zone 3, 12% in zone 1, and 10% in zone 4. These zones had average peak period weekday temperatures of 24.5ºC, 28.8ºC, 21ºC and 34 ºC respectively for July-Sept 2003/4.
Period covered:	July 2003-December 2004
Sample size:	2500 participants selected by a stratified random sample.
Consumer categorisation:	Track A consumers were selected from consumers with average summer energy use above 600kWh per month. Track C consumers were selected from a sample that had volunteered for a previous smart thermostat pilot. Average income for track A participants was higher than the population average.
DSR categorisation:	The following price structures were piloted: • a traditional ToU structure, where the peak price was roughly double the off-peak price; • critical peak pricing (CPP) with a fixed critical peak price

Overview	
	(roughly 6 times higher than the off-peak price) with a fixed critical peak period and day ahead notification (CPP-F); • CPP with a fixed critical price (again roughly 6 times higher than the off-peak price) but with a variable peak period on critical days and on the day notification (CPP-V); and • an information only plan that encouraged consumers to reduce demand on critical peak days, without time-varying prices. • CPP-V consumers could have an enabling technology installed if they did not already have enabling technology. 60% of consumers in CPP-V track A, zone 2, chose an enabling technology, and 75% in zone 3. Track C consumers on the CPP-V tariff were selected from consumers that had volunteered for a smart thermostat pilot.
Incentives for participation:	Participants were given a $175 thank you payment in instalments, tied to completing a survey, remaining on the rate until the end of summer 2003, and remaining on the rate until the end of April 2004. The pricing programmes were required: • to be revenue neutral for the average consumer (in each class) over a calendar year, absent a change in their load shape; • to not change the bill of high/low users by more than 5%, absent a change in their load shape; and • to enable participants to reduce their bill by 10% if they reduced or shifted peak usage by 30%. Low-income households (<$23k income for a 1-2 person household, and <$43.5k for a 6 person household) qualified for a 20% discount on their electricity bill.
Other relevant features:	80% of CPP-V track A consumers had central air conditioning (a higher proportion than the overall population). All CPP-V Track C consumers had smart thermostats and central air conditioning. The CPP-V results are not directly comparable to the CPP-F results, due to population differences.

Overview	
Information and enabling technologies:	Consumers received a shadow bill at the start of the pilot and after one year, projecting their likely bill under their new tariff, and comparing it to their bill on their existing tariff, with different load shifting assumptions. They could request an additional shadow bill at any time. Participants were also sent a summary sheet showing: • their electricity usage by pricing period for the billing cycle; • how much they paid; and • the implicit price for each period (in cents per kWh).
Consumer take up of DSR tariffs/schemes	Enrolment packages were sent to 8679 consumers, resulting in enrolment of 1759 treatment participants for summer 2003.
Summary of results	
Assumptions:	.
Implications for key questions	
What behaviours changed?	The pricing plans had the following load shifting effects. • **CPP-F:** 13.1% average reduction in peak-period energy usage on summer critical peak days, and 4.7% for normal summer weekdays. Average load shifting on critical peak days for consumers on the CPP-F tariff was greater for the hotter summer months (July-September) than the milder months (May, June and October). Load shifting for these consumers was lower in winter than summer. • There was almost no conservation effect found for CPP-F consumers - electricity usage reductions in peak periods were almost entirely offset by increased off-peak usage. • **CPP-V:** The results of the CPP-V tariff trial were broken down into results for the Track A and Track C samples: **Track A:** Average (across households with and without enabling technology) reduction in peak-period energy use of 15.8% for critical peak days in summer 2004, and 6.7% for normal weekdays in the same period. • **Track C**: 27% reduction in usage from peak periods, of which

Overview	
	about 2/3 can be attributed to automated response (enabling technology) • **Information only:** For the two zones where this was introduced, there was a statistically significant effect for only one zone in 2003, and no evidence of load shifting for either zone in 2004.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	For track A consumers in the CPP-V tariff, binary variables for an enabling technology and a smart thermostat were found not to be statistically significant in affecting peak period electricity demand. However, the authors suggest that the lack of an effect found could be due to relatively small samples with and without the technology. In addition, load analysis showed that the technologies to control pool pumps and water heaters had little impact on peak period demand, possibly because pool pumps were already on timers, and water heating represented a small part of peak summer loads.
Did different consumers behave differently?	Results were broken down by consumer characteristics for the analysis of the CPP-F tariff, and these are summarised below. Participants with central air conditioning had greater load shifting than those without. Average daily energy usage had only a small effect on load shifting. Smaller households and higher income households were more responsive to price changes.

Overview	
	Load shifting also differed by education level of the head of household: where the head of household was a college graduate, the reduction in peak electricity usage on critical peak days was 18.5%, compared to 8.6% for households where the head of household had not graduated from college. Low-income participants (those who received the CARE discount) were less price responsive: their price elasticity of substitution was roughly zero. Results for other tariffs were not broken down by consumer characteristics.
Are the results consistent over time?	CPP-F: The evidence from the tariff suggested that peak load shifting persisted over time, as differences in critical peak load shifting on summer days were not statistically significant between 2003 and 2004. ToU: The tariff resulted in a 5.9% average reduction in peak energy use for "inner summer" (July-September) 2003, but only a 0.6% effect for the same period in 2004. The paper stressed that the result was tentative due to a small sample size (226 consumers on the ToU tariff, split over four climate zones), but it could suggest that the effects of a ToU tariff alone are unsustainable. Information only: This was introduced in two zones, and there was a statistically significant effect for one zone in 2003, and no statistically significant load shifting effect in either zone in 2004. CPP-V: There were two groups on this tariff. Suitable data for the Track A sample was available for summer 2004 only. For track C consumers, the main analysis pooled 2003 and 2004 data, but separate regressions showed that the value of the elasticity of substitution decreased by approximately 50% between 2003 and 2004, but the coefficient on the enabling technology remained unchanged.

Source: Frontier Economics

Table 8. CL&P Plan it Wise Pilot (2009)

Overview	
Title of study:	Results and Appendices of CL&P Plan-it Wise Energy Pilot
Author(s):	The Brattle Group for CL&P
Date:	2009
Source:	Results: http://www.cl-p.com/Home/SaveEnergy/Plan-it_Wise_Pilot_Results/ See these Appendices for more details: http://www.cl-p.com/Home/SaveEnergy/Plan-it_Wise_Pilot_Results_Appendix/
Categorisation	
Country/region:	Connecticut, USA
Period covered:	June 1 2009—August 31 2009
Sample size:	2437 consumers in the sample (of which 1251 were residential), and an additional control group of 200. Consumers were randomly selected into a rate, pricing and technology option and were not able to switch.
Consumer categorisation:	77% of residential participants were homeowners. The highest level of educational attainment was a college graduate or postgraduate degree for 54% of participants. Household income was less than $50k for 37% of participants, between $50k and $100k for 20%, and above $100k for 20% (23% preferred not to answer). 154 residential participants (more than 10% of residential participants) were low-income/hardship consumers, consistent with their overall population representation.
DSR categorisation:	The following price structures were tested. • critical peak pricing (CPP); • critical peak rebate (CPR); and • ToU with peak hours from noon-8pm on weekdays. For each of these tariffs, a high and low on/off-peak differential was tested. 10 critical peak days were called during the pilot,

Overview	
	each running from 2-6pm. Some participants received enabling technologies, of which two were controlling, and two provided information only.
Incentive for participation	On average, residential consumers saved $15.21 during the pilot, and low income consumers saved $8.07. Residential consumers that used the website saved more (on average $24.69)
Other relevant features:	43% of residential participants had central air conditioning. Weather was relatively mild during the period, implying more muted responses to critical peak days than would have been typical.
Information and enabling technologies	Smart meters that recorded hourly electricity usage were installed for all consumers. In addition, four enabling technologies were tested for some consumers: • two controlling technologies: automatic set-back thermostats and automatic switches on central air conditioners two information-only technologies: the Energy Orb, which provided information on when peak events were happening; and the Power Cost Monitor in-home display, which showed real-time electricity usage and pricing. The controlling technologies allowed an automated response to critical peaks. All participants could access their energy usage online by hour, day or week. Participants with automatic switches could override them by calling the company, and participants with smart thermostats could override them more easily.
Consumer take up of DSR tariffs/schemes	3.1% of residential consumers contacted to take part in the trial enrolled. A survey of 205 residential participants found the following. • 92% of residential consumers would participate in the pilot again, and overall satisfaction was on average rated 5.1 out of 6; • CPP was rated the most satisfying pricing structure, and the ToU was the least satisfying; and

Overview	
	• the smart switch was the most satisfying technology.
Implications for key questions	
What behaviours changed?	For residential consumers facing the higher peak/off-peak price differentials, critical peak usage reductions were: • 23.3% for CPP consumers with controlling technologies, and 16.1% without; • 17.8% for CPR consumers with controlling technologies, and 10.9% without; and • 3.1% for eight-hour ToU consumers, with no effect of controlling technologies. See Slide 8 of the appendix for more details. See Slide 15 for a comparison of the residential demand response impacts with other pilots.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	Focus groups of elderly and low-income participants requested more information be provided for ToU consumers and fewer phone calls to CPP and CPR consumers.
What worked to alleviate the barriers?	• Controlling technologies (a smart thermostat/ smart switch) resulted in an extra reduction of peak electricity usage of up to 7%. • Non-controlling technologies (the Energy Orb and Power Cost Monitor) had no significant effect on peak electricity usage.
What role did incentives play?	**Economic:** 86.2% of residential participants stated they participated in the pilot to save money. **Non-economic:** 67% of residential consumers listed the positive impact on the environment as a motivation for joining the pilot. Those that joined the pilot for environmental reasons were more satisfied than those that joined to save money.

Overview	
Did complexity matter?	80% of consumer calls regarding technology were about smart thermostats.
How important was automation?	Participants that received controlling technologies (which enable an automated response) had larger reductions in peak electricity use than those without.
Did different consumers behave differently?	The findings from focus group sessions for limited-income and elderly participants following the pilot were similar to the results from the post-pilot survey. Key messages from the focus groups were: • The main reason for enrolling was to save money, with only a few mentioning the impact on the environment. • ToU participants felt 12pm—8pm was too long for a peak period, and that the peak/off-peak price differential was too small. • Most participants said they did change their behaviour during the pilot.
Are the results consistent over time?	The survey ran for one summer only.

Source: Frontier Economics

Table 9. Energy Australia (2006-2008) and Integral Energy Trial (2006-2008)

Overview	
Title of study:	Smart Meter Consumer Impact: Initial Analysis
Author(s):	Energy Market Consulting Associates
Date:	February 2009
Source:	http://www.ret.gov.au/Documents/mce/_documents/smart_meters/Smart%20meter%20consumer%20impact%20analysis%20-%20EMCa%20report.pdf
Categorisation	

Overview	
Country/region:	Australia
Period covered:	2006—2008
Sample size:	The Energy Australia trial included 750 residential consumers. The Integral Energy trial included 900 residential consumers, and an additional control group of 360.
Consumer categorisation:	Integral Energy trial 25% of the sample had incomes below AUD$30k, 41% had incomes between AUD $30k and AUD $75k, and 34% had incomes above AUD $75k.
DSR categorisation:	Two trials were covered, one implemented by Energy Australia, and the other by Integral Energy. **Energy Australia trial** Participants faced five different treatments: • information only (enhanced billing); • seasonal time of use (SToU) tariff; • a low dynamic peak price (DPP) tariff; • a high DPP tariff without in-home display (IHD); and • a high DPP tariff with IHD. **Integral Energy trial** Participants were placed on one of three different tariffs. • SToU tariff with peak periods differing for winter and summer; • DPP tariff with peak (1pm—8pm on critical peak days), shoulder (1pm—8pm on working days), and off-peak rates; and • DPP with IHD. The control group were on a block tariff with a higher price for electricity usage above a threshold. Rates are detailed in Table 1 of the paper.
Incentives for participation:	**Integral Energy trial** All consumers received $100 (all monetary amounts in

Overview	
	Australian dollars) for joining the trial, and $200 upon completion. On average, DPP IHD participants saved $300 during the two year trial, of which $100 was due to non-revenue-neutrality, and $200 was due to behaviour change. Savings were consistent across different levels of income. No information is available on incentives for participation in the Energy Australia trial.
Other relevant features:	**Integral Energy trial** • 88% of the sample (treatment and control groups) used air conditioning; • 82% of the sample had ceiling insulation; and • 45% had 4 bedroom homes, 51% had 3 bedroom homes, and 3% had 2 bedroom homes.
Information and enabling technologies:	Results on enhanced information and enabling technologies were only available for the Integral Energy trial, and are summarised below. Smart meters were installed for all participants. All participants received a welcome pack and could monitor their electricity use online. DPP IHD participants could monitor their electricity usage using the in home display.
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	**Energy Australia trial** • electricity consumption reduced by 5-7% on DPP days; • reduction of overall usage, rather than load shifting, occurred; and • electricity usage reductions were similar for winter and summer. • electricity usage by the information-only group did change, but

Overview	
	their responses were more variable than the other trial groups. **Integral Energy trial** Critical peak electricity use was reduced by: • 37% for DPP consumers; and • 41% for DPP IHD consumers.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	There was none built into the trial.
Did different consumers behave differently?	-
Are the results consistent over time?	**Integral Energy trial** DPP and DPP IHD participants still reduced peak usage when consecutive critical peak days were called.

Source: Frontier Economics

Table 10. ETSA Utilities Trial (2005-2010)

Overview	
Title of study:	Demand Management Program Interim Report No. 3

Overview	
Author(s):	ETSA Utilities
Date:	June 2010
Source:	www.etsautilities.com.au/public/download.jsp?id=11891
Categorisation	
Country/region:	South Australia
Period covered:	2005-2010
Sample size:	Sample sizes were usually small, and varied between the different trials. The direct load control trials included samples of 20, 30, 142 and 754 consumers. The distribution peak pricing trial sample consisted of 20 households with data collected. The community based marketing programme was aimed at 12,000 households.
Consumer categorisation:	-
DSR categorisation:	A number of different demand-side management trials were run. **Direct Load Control** • Phase I: 20 consumers in the Adelaide metropolitan area had their air conditioning externally controlled by forced cycling. • Phase II (a): this installed Peakbreaker controllers to the external compressors of 754 air conditioning units, and aimed to better understand the technology and consumer acceptance of it. • Phase II (b): this installed more advanced Peakbreaker technology for 30 volunteers. • Phase III: Direct load control technology was installed for 142 consumers, and they were monitored using interval meters. "**Distribution Peak Pricing (DPP)**," where electricity was more expensive during network distribution constraining events. Participants were notified by beeping of a "Peakbreaker

Overview	
	technology", and a flashing red light during peak events. Data was successfully obtained from 20 participants. **Non-economic:** A community-based social marketing and education campaign named “Beat the Peak” was used. This was aimed at 12,000 residences and commercial premises in Glenelg, as well as the wider community.
Incentives for participation	**Direct Load Control Phase II** Consumers were paid $100 (Australian dollars) for participation.
Other relevant features:	Daily peaks in demand for the sample are pronounced compared to other countries.
Information and enabling technologies:	CPP trial participants already had interval meters installed.
Consumer take up of DSR tariffs/schemes	5.5% of consumers responded to recruitment letters for the DPP trial.
Implications for key questions	
What behaviours changed?	**Direct Load Control** • Phase I-Forced cycling of air conditioner compressors lowered demand by an average of 17%. • Phase III-The average kW reduction in load for participants in Glenelg (an older suburb) was 0.45, and 1.34 for participants in Mawson Lakes (a newer suburb with higher temperatures). **DPP** • During summer critical peaks, the most common responses were to turn off air conditioning, the computer or TV. During winter, the most common appliance switched off in response to an event was the TV.
What barriers were identified to moving demand (by category e.g. economic,	-

Overview	
complexity, housing/appliance, lifestyle)?	
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	Where results were reported, they showed that automation reduced peak period demand.
Did different consumers behave differently?	-
Are the results consistent over time?	-

Source: Frontier Economics

Table 11. Ireland Electricity Smart Metering Customer Behaviour Trials (2009-2010)

Overview	
Title of study:	Electricity Smart Metering Customer Behaviour Trials (CBT) Findings Report and its appendices
Author(s):	Commission for Energy Regulation
Date:	16th May 2011
Source:	All available at http://www.cer.ie/en/information-centre-reports-and-publications.aspx?article=5dd4bce4-ebd8-475e-b78d-da24e4ff7339&mode=author
Categorisation	
Country/region:	Ireland

Overview	
Period covered:	2009-2010
Sample size:	5028 participants
Consumer categorisation:	-
DSR categorisation:	Participants were allocated to one of four time of use (ToU) tariffs with night, day and peak prices. Weekend prices were all flat. In addition they received a specified combination of: • a bi-monthly electricity bill with a detailed energy statement; • a monthly electricity bill with a detailed energy statement; • an electricity monitor; and • an Overall Load Reduction (OLR) incentive. Details are specified in Tables 2-3 in the paper. The ToU tariff was designed to be revenue neutral compared to the standard tariff.
Incentives for participation: :	Residential participants received a thank you payment of €25 for upon completion of each survey (one pre-trial, one post-trial). In addition, participants received balancing credits in December 2009 and January 2011, which were payments of small set amounts to make sure that they did not lose money by taking part in the trial (amounts detailed in Table 4). Any participants that had made a loss greater than the credit under the trial tariff were additionally compensated.
Other relevant features:	-
Information and enabling technologies:	All participants received a fridge magnet displaying their ToU prices and a sticker which displayed the time bands. Some participants received an electricity monitor, which provided information on electricity usage and cost, and enabled consumers to set a daily maximum spend with which they could compare usage. The OLR incentive set a 10% target reduction in electricity usage for the participant, based on the participant’s previous usage. Bi-monthly bills updated participants with their progress

Overview	
	towards the target. If they achieved this over eight months, participants received a €20 reward.
Consumer take up of DSR tariffs/schemes	The average response rate to recruitment was 30%.
Implications for key questions	
What behaviours changed?	On average, peak electricity usage reduction by domestic participants with ToU and demand side management stimuli was 8.8% relative to the control group. Peak reductions range from 7.2-10.9% across the four tariff types. As a consequence of participation in the trial, 74% of participants made minor changes to their electricity usage, and 38% made major changes. 79% reported that they became more aware of the amount of electricity used by appliances, and 78% became more aware of the cost of electricity used by appliances.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	**Economic:** "The difficulty of linking behaviour change to bill reduction" (p.9) acted as a barrier to shifting demand. The expected savings that could be made from shifting demand were larger than the actual savings that could be made. **Complexity:** There was a low recall rate of the OLR incentive (58%), but it received good scores for communications, effectiveness, and having a reasonable target. **Lifestyle:** Safety and convenience concerns acted as barriers to shifting to night usage. **For participants that had not reduced peak/overall usage:** • 59% agreed that they tried to reduce usage but the bill seemed the same so they gave up; • 29% agreed that they did not know enough about how and when they used electricity to reduce peak usage (55% disagreed); and • 28% agreed that the difference between the peak and non-peak prices was too small to make them shift usage (53% disagreed).

Overview	
What worked to alleviate the barriers?	The combination of the bi-monthly bill, energy statement and electricity monitor were the most successful at reducing peak electricity usage. • 75% found the fridge magnet useful and 63% found the sticker useful. • 91% rated the electricity monitor as an important support for achieving peak reduction, and 87% rated it as an important support for shifting to night rates.88% agreed that it was easy to use.
What role did incentives play?	-
Did complexity matter?	Participants found it hard to calculate the likely impact of shifting demand on their bills. Bill and peak usage reductions tended to be overestimated by participants.
How important was automation?	There was none built into the trial.
Did different consumers behave differently?	The impact of education/social grade on electricity usage reduction was found to be limited once higher usage by high educational achievement/ social grade households is taken into account. Households receiving the Free Electricity Allowance (the elderly, carers with specified allowances, and individuals receiving specified disablement benefits), who are sheltered from the ToU tariffs, had lower peak electricity usage reduction than average. Fuel poor households were found to benefit from ToU tariffs. Peak usage reduction was higher (10.7% compared to 6.5%) for households with children under 15 years in the home. Focus group responses indicated that this was due to children below the mid-teens motivating change and energy reduction for the household, driven by school initiatives.
Are the results consistent over time?	The results gave no clear picture as to whether the results change over time. Overall usage reduction was slightly smaller in the 2nd six months than the 1st six months, but peak usage reduction increased.

Table 12. LIPA Edge (2001-2003)

Overview	
Title of study:	International Best Practice In Using Energy Efficiency and Demand Management to Support Electricity Networks
Author(s):	David Crossley, Energy Futures Australia
Date:	December 2010
Source:	http://www.efa.com.au/Library/David/Published%20Reports/2010/InternationalBestPracticeinEEandDSMforNetworkSupport.pdf
Categorisation	
Country/region:	In its appendix, the paper reviews a number of DSR trials. This table covers only the LIPA Edge programme (Case Study 9), which took place on Long Island.
Period covered:	2001-2003
Sample size:	20,400 residential participants
Consumer categorisation:	-
DSR categorisation:	Participants' central air conditioning was directly controlled by the Long Island Power Authority (LIPA) during curtailment events, which occurred from 2—6pm for a maximum of seven days during the summer season. During curtailment events, LIPA cycled air conditioning compressors for a part of each hour, or increased the set point on the thermostat. No economic incentive was trialled.
Incentives for participation:	Residential participants received a free ComfortChoice thermostat and installation, as well as a bonus payment of $25. Participants could also earn $20 for referring new participants.
Other relevant features:	All participants had central air conditioning.
Information and enabling technologies:	Participants received a programmable thermostat with two-way communication. Participants could control their thermostat remotely, and were able to override direct control by the LIPA, though this override could in turn be blocked by the operator.

Overview	
	The programme cost LIPA $515 per residential participant. On average (for residential and commercial participants), the average cost of demand reduction was $487/kW.
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	Each controlled residential air-conditioner provided on average a 1.03 kW reduction in demand during a curtailment event (the average capacity of residential air conditioning units was 3.84 kW).
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	It was found that the ability of participants to override direct control of the thermostat during a curtailment event was important for gaining participant acceptance.
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	Demand reduction during a curtailment event came from direct control of air-conditioning thermostats. The percentage of units that had been overridden during a curtailment event from 2-6pm in August 2002 increased from 5.7% at the hour ending 3pm to 20.8% at the hour ending 6pm.This meant that the total demand reduction decreased over the curtailment period.
Did different consumers behave differently?	-
Are the results consistent over time?	-

Source: Frontier Economics

Table 13. Norway DSR Pilot Study (2010)

Overview	
Title of study:	Demand Response from Household Customers: Experiences from a Pilot Study in Norway
Author(s):	Hanne Sæle and Ove S. Grande
Date:	March 2011
Source:	IBEE Transactions on Smart Grid, Volume 2, No. 1, March 2011
Categorisation	
Country/region:	Norway
Period covered:	1 year
Sample size:	40 households, from the same geographic area and with hourly electricity metering above a certain quality. The paper states that these households were not randomly selected.
Consumer categorisation:	-
DSR categorisation:	The trial consisted of a ToU tariff (a morning and evening peak period on weekdays) and direct control (during peak periods only).
Incentives for participation:	-
Other relevant features:	10% of participants had hot water space heating with an electric boiler. The remaining participants had standard capacity electric boilers.
Information and enabling technologies:	The communications materials provided for participants gave information on the benefits of demand response. Participants were given hourly metering with use of existing automatic meter reading technology. Two information meetings were held to inform participants about the pilot (e.g. peak hours and pricing, and the

Overview	
	possibilities for demand shifting). Participants could compare the pilot tariff with the standard tariff online. Participants each received 3 magnets to place on appliances, displaying morning and afternoon peak hours. Under the direct control regime, a response of electric water heaters was automated during peak periods. Installation costs for remote load control were 80-375 € per participant.
Consumer take up of DSR tariffs/schemes	Survey results indicated that participants perceived the pilot positively. The main focus of this was personal economic benefit, followed by reduced consumption of electricity. Participants accepted remote load control, provided it didn't reduce their comfort.
Implications for key questions	
What behaviours changed?	The average reduction in morning peak load was 1kW per hour for participants with standard electric water heaters, and 2.5kW per hour for participants with hot water space heating systems. Several participants adapted their behaviour to the ToU tariff, by: • investing in energy control systems; • buying firewood in winter; and • manual efforts.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	This trial found a larger average peak load reduction compared to a previous pilot[121] was taken to indicate that participants were manually reducing peak load, as well as reducing load via direct control. The paper suggested that this could be the result of introducing the peak period reminder magnet for

[121] Grande, O. S., Sæle, H., and Graabak, I., SINTEF Energy Research, 2008, Market based demand response. Research project summary 2008.

Overview	
	appliances, which was not included in the previous pilot.
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	All consumers faced economic incentives to shift load (the ToU tariff) and direct control, so it is not possible to isolate the impacts of each intervention.
Did different consumers behave differently?	-
Are the results consistent over time?	The peak usage reductions found were larger than estimates for a similar trial conducted previously. This could be due to the use of magnets reminding participants of peak hours, though the sample size (40 participants) is small.

Source: Frontier Economics

Table 14. Ontario Energy Board Smart Price Pilot (2006-2007)

Overview	
Title of study:	**Ontario Energy Board Smart Price Pilot Final Report**
Author(s):	**IBM and eMeter Strategic Consulting**
Date:	**July 2007**
Source:	http://www.oeb.gov.on.ca/documents/cases/EB-2004-0205/smartpricepilot/OSPP%20Final%20Report%20-%20Final070726.pdf
Categorisation	
Country/region:	Ontario
Period covered:	August 2006-February 2007

Overview	
Sample size:	373 of Hydro Ottawa's electricity consumers that already had smart meters installed by Aug. 1 2006, in 3 groups with different tariffs: • 124 time of use (ToU) only; • 124 ToU and critical peak price (CPP); and • 125 ToU critical peak rebate (CPR). In addition, there was a control group of 125 consumers selected randomly from Hydro Ottawa residential consumers with smart meters installed before Aug. 1 2006, paying regular tiered (non-ToU) prices. Participants were recruited by a stratified random sample to ensure sufficient low/med/high electricity consumers. All reported load shifting is statistically significant unless otherwise indicated.
Consumer categorisation:	72% of homes in the pilot were built after 2001.81.9% of participants that responded lived in single-family homes and 11.7% in apartments with less than 5 floors. The highest level of educational attainment was: some high school education for 1% of responding participants, high school graduate for 16%, and university or college graduate for 83%. 11% of pilot participants had household income less than $50k, 43% $50-$100k, and 47% had household income above $100k.
DSR categorisation:	The following three price structures were tested. • Regulated Price Plan (RPP) time of use (ToU). This included on-peak, mid-peak, and off-peak prices. Prices and peak hours varied between summer and winter. • Adjusted RPP ToU prices with a critical peak price. • RPP ToU prices with a critical peak rebate. Critical peaks lasted for 3 or 4 hours, and a maximum of 9 critical peak days were allowed (only 7 were implemented due to mild weather). The CPP was set based on the 93 highest hourly Ontario electricity prices in the previous year. The CPR was 30 cents for every kWh reduction below the participant's "baseline" usage during critical peak hours.

Overview	
	All participants were regulated price plan (RPP) consumers. The RPP consists of two prices, one for monthly consumption below a threshold, and a higher price for consumption above the threshold. These thresholds vary by season, and are chosen so that forecast consumption is split approximately 50/50 into the two tiers. *Peak hours and prices:* Off-peak hours were 10pm-7am weekdays, and all weekends and holidays. Price/kWh was 3.5c for summer, and 3.4c for winter *Mid-peak hours were:* • 7am-11am and 5pm-10pm weekdays, at 7.5c/kWh (summer) • 11am-5pm and 8pm-10pm weekdays, at 7.1c/kWh (winter) • On-peak hours were: • 11am-5pm weekdays, at 10.5c/kWh (summer) • 7am-11am and 5pm-8pm weekdays at 9.7c/kWh (winter) The critical peak rebate was set equal to the critical peak price during critical peak hours (to try and achieve revenue neutrality[122] between the CPR/CPP schemes). The CPR baseline (consumption below which the rebate was paid) was the participant's average usage for the same hours over the previous 5 non-event weekdays, increased by 25% to reflect higher usage on critical peak days.
Incentives for participation	"Thank you" payments of $75 were received at the end of the pilot, adjusted by the participant's savings/losses under ToU pricing. This accompanied by a final settlement statement comparing the participant's charges on the pilot vs. the two-tiered RPP prices. The average saving was 3% compared to the non-ToU bill. During the pilot, participants continued to receive and pay their usual bi-monthly electricity bill, and separately received monthly Electricity Usage Statements showing their electricity supply charges on their pilot price plan. The top reasons given in feedback for participating in the pilot

122 ""Revenue neutral" was defined such that a participant whose electricity usage is distributed across the hours in the same way as the provincial average for all RPP consumers would pay approximately the same bill on all three options (and the tiered RPP prices) in the absence of any change in usage." (p.41)

Overview	
	were: • consumers wanted to be prepared for the arrival of ToU pricing by seeing the economic effects on them of ToU pricing; • consumers liked the idea of being able to monitor their electricity usage; and • participants perceived that they would have more control over their electricity bill due to the design of ToU pricing and feedback on their usage. (i.e. the $75 thank you was not in the top motivations for most respondents)
Other relevant features:	91.3% of the 319 participants that responded had air conditioning. 82.3% had gas space heating, and 8.6% electric heating. 84.4% used gas or oil water heating, and 14% used electric water heating. The trigger temperatures for a critical peak were 28ºC in summer and -14 ºC in winter, or when the Humidex is higher than 30 ºC during on-peak periods. However, for 2/7 critical peak days, these thresholds weren't reached, and for most they were just exceeded. Mild weather may have affected the results, as other pilots have found less load shifting during mild rather than extreme weather.
Information and enabling technologies:	All participants (treatment and control) already had smart meters installed. Participants were sent a table of ToU prices, periods and seasons for their plan on a fridge magnet, and a PowerWise electricity conservation brochure after enrolling.
Consumer take up of DSR tariffs/schemes	The trial was over-subscribed within a week of the recruitment letter: 1800 letters were sent to consumers with smart meters, and 459 sent an enrolment form before close (a 25.5% response rate). 78% of 298 survey respondents (a 79% response rate) would recommend the ToU tariff to a friend, while 6% would definitely not. The top 3 reasons given for satisfaction were: • awareness of how to reduce bill; • greater control over electricity costs; and • environmental benefits. Reasons for not recommending ToU were:

Overview	
	• insufficient potential savings; and • too much effort. Of the four pricing schemes, 74% (regardless of the pricing plan they were enrolled on) preferred ToU-only, while <20% preferred the existing (two-tier threshold) pricing.
Implications for key questions	
What behaviours changed?	Load shifting on critical peak days: For all three groups, a statistically significant (at the 90% level) load shift away from on-peak periods occurred on the two critical peak days in August, while there was no statistically significant shift for the critical peak days in September or January (apart from one counterintuitive result for Jan 17). Load shifting away from critical peak hours for all the summertime critical peak days ranged from 5.7% (ToU-only group) to 25.4% (CPP group). Load shifting on all days: No statistically significant load shifting away from on-peak periods was observed from the ToU price structure alone. On average there was a reduction in usage of 6% (statistically significant) for all treatment consumers. Specific actions changed by focus group respondents to shift electricity use off-peak were changing the time of laundry and dishwashing, and adjusting thermostats before a critical peak.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	**Economic:** "No one felt as if the ToU prices were the "money grab" and "gouging" that many had feared and/or perceived going into the pilot." (p.52/3) **Housing/appliances:** Some participants with timers on dishwashers and programmable thermostats first used these after the pilot started. The focus group mainly felt that there was no more additional shifting they could achieve during a critical peak, as they had reduced electricity consumption to their minimum already in response to on-peak prices.
What worked to alleviate the barriers?	Focus group (of 44 participants) and survey respondents found the monthly usage statement and fridge magnets were the most useful resources for understanding ToU prices (over fact sheet/brochure/other communication materials). The fridge

Overview	
	magnets were favoured as they were clear, concise, and durable. • 61% of responding participants preferred that information on the time periods was displayed in a table, rather than in a graphic. • Almost 70% of survey respondents anticipated accessing an online statement at least once a month.
What role did incentives play?	Participants could gain or lose via load shifting only, as the adjustment to the $75 "thank you" was calculated by comparing the participant's bill under ToU prices vs. two-tiered RPP prices. On average, bills were 3% lower for participants, and ¾ made a saving relative to tiered RPP prices due to load shifting. 71% of survey respondents felt the differences in prices between periods were large enough to encourage them to shift electricity consumption.
Did complexity matter?	The consensus in the focus group was that ToU pricing was easy to understand and no participants said they wanted to change from a three period to two period ToU structure.
How important was automation?	There was none built into the trial.
Did different consumers behave differently?	**Lifestyle:** Some families with small children found it difficult to reduce laundry during mid- and on-peak periods (though these families did not feel penalised for this under ToU prices).
Are the results consistent over time?	-

Source: Frontier Economics

Table 15. Pacific Gas and Electric Company's Time-Based Pricing Tariffs (2008-2010)

Overview	
Title of study:	2010 Load Impact Evaluation of Pacific Gas and Electric Company's Time-Based Pricing Tariffs, Final Report

Overview	
Author(s):	Freeman, Sullivan & Co.
Date:	April 1 2011
Source:	http://www.fscgroup.com/news/pge-2010-residential-pricing-programs-evaluation.pdf
Categorisation	
Country/region:	California, USA
Period covered:	Most results reported are for 2009-10, some span 2008-10.
Sample size:	Roughly 25,500 consumers were on the SmartRate. Consumers volunteered for the SmartRate programme
Consumer categorisation:	SmartRate Median household income was $62,921, median age per household was 33 years, average household size was 3.48, 66.1% spoke English at home, and 15.4% were college educated.
DSR categorisation:	The following three tariffs were in effect in 2010. • SmartRate, which has a high peak price from 2pm-7pm on event days, and lower prices at all other times during summer. • Rate E-7, which has a peak period from 12pm-6pm, and five consumption tiers • Rate E-6, which has three periods, a peak from 1pm-7pm in summer, and a "partial peak" from 5-8pm in winter, and five consumption tiers (see Table 2-5 in the paper for E-6 and E-7 prices) In addition, roughly 20% of SmartRate consumers in 2010 had enabling technology as they were also enrolled on "SmartAC" SmartRate overlays the consumer's original tariff. The most common residential tariff had five tiers, with prices increasing for each usage tier. (Details in Table 2-1 of the paper)
Incentives for participation:	SmartRate consumers received protection for the first year after enrolment, which this ensured the first year bill did not rise compared to what it would have been on the original tariff. 88% of SmartRate consumers had lower bills relative to the

Overview	
	otherwise applicable tariff. Average savings over a year for ToU consumers were 18%.
Other relevant features:	-
Information and enabling technologies:	Some consumers had enabling technology installed for their air conditioning.
Consumer take up of DSR tariffs/schemes	Take-up of SmartRate by CARE (low-income) consumers was higher than take up by non-CARE consumers. CARE consumers represented roughly half of SmartRate consumers, compared to around a quarter of the PG&E residential population.
Implications for key questions	
What behaviours changed?	**SmartRate:** Average peak load reductions in 2010 on the 13 event days were 14.1% (15% in 2009). The average reduction for a given event day ranged between 5.7% and 22.8%. 36% of consumers did not reduce peak demand at all during event days, though ¼ of these consumers had not received notification of the event. **ToU:** The average peak period load reduction for 2009-10 was 11%.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	Percentage peak load impacts on event days were 65% larger for households with more than a 75% probability of owning air conditioning, compared to those with less than 25% probability of owning air conditioning.
What worked to alleviate the barriers?	-
What role did incentives play?	-

Overview	
Did complexity matter?	-
How important was automation?	The peak demand reduction during events for SmartRate consumers with enabling technology for air conditioning was 23% higher than for those without.
Did different consumers behave differently?	Average peak demand reduction on event days for CARE consumers (low income consumers that receive a discount on their electricity bills) was 6.6% compared to a reduction of 21.4% for non-CARE consumers. When differences in underlying characteristics (such as air conditioning ownership) were controlled for, peak demand reductions were not significantly different between CARE and non-CARE consumers. It should be noted when comparing results for CARE and non-CARE consumers that the structure of the underlying tariff and the way the discount was applied meant that the economic incentives to shift demand were different for the two groups.
Are the results consistent over time?	Three years of evidence from the SmartRate programme indicate that peak demand reductions did not decline over time.

Source: Frontier Economics

Table 16. PowerCentsDC Trial (2008-2009)

Overview	
Title of study:	PowerCentsDC Program Final Report
Author(s):	eMeter Strategic Consulting
Date:	September 2010
Source:	http://www.powercentsdc.org/ESC%2010-09-08%20PCDC%20Final%20Report%20-%20FINAL.pdf
Categorisation	

Overview	
Country/region:	District of Columbia (DC), USA
Period covered:	July 2008-October 2009
Sample size:	900 participants. Participants were selected by stratified random sampling from the District to participate in a single price plan. A control group was created by installing smart meters for a random selection of 400 non-participants. These consumers remained on the standard offer service (SOS)[123].
Consumer categorisation:	19% of participants reported household income below $50k, 19% $50-75k, 14% $75-100k, and 46% reported income above $100k. Low-income consumers were included only on the critical peak rebate (CPR) programme, as no loss could be made on this. The trial included a low number of low-income participants, as they were a low proportion of the population (7.6% qualified for regular limited income electricity rates), and many limited income consumers changed address between recruitment and the program starting, resulting in them dropping out of the trial. 81% of participants were homeowners and 19% were renting. 31% of responding participants lived in one person households, 39% lived in two person households, and 30% lived in households with three or more people. The highest level of education achieved was high school graduate for 8% of participants, some college/university for 12%, a college/university degree for 24%, and a postgraduate degree for 54%.
DSR categorisation:	The following three price structures were tested. • Critical Peak Pricing (CPP);

123 The SOS is a two (sometimes three) tiered tariff, where the thresholds vary by season and customer rate schedule (residential, residential with electric heating, customers with limited income, and limited income with electric heating).

Overview	
	• Critical Peak Rebate (CPR); and • Hourly Pricing (HP)—prices were based on day-ahead wholesale prices and changed hourly. Critical peaks occurred for four hours, on 15 days per year. (In the study, 3 occurred in winter and 12 in summer). CPP and CPR participants were notified by phone, email, or text message the evening before a critical peak event. The prices faced by CPP consumers were set to try and ensure revenue neutrality compared to the SOS bill over 12 months. Baseline consumption for CPR participants was calculated as the average of the three highest non critical peak usage amounts for non-holiday weekdays during the billing month. No adjustment was made to the SOS price charged during the rest of the year. Prices for HP consumers were set a day in advance based on the day-ahead wholesale market. Prices were displayed in real-time on smart thermostats, online, and at a free telephone number. Consumers were notified a day in advance if prices exceeded a threshold (which was reduced during the trial due to falling wholesale prices). For specific price details, see Exhibits 8-10 in the paper.
Incentives for participation:	“Thank you” payments of $100 were paid to CPR and HP participants, half as an upfront incentive, and half at the end of the pilot. CPR consumers received a $25 payment for completing the participant survey.
Other relevant features:	44% of participants that responded lived in a condominium/townhouse/duplex, 28% in a single family detached house, and 15% in an apartment.81% of participant homes were built before 1980. 97% of participants had air conditioning. 54% had gas heating, 13% electric heat pump, 10% electric furnace, and 8% hot water baseboard. 62% had gas water heating, and 28% had electric water

Overview	
	heating. Winter data for consumers with smart thermostats was excluded from the analysis, as the thermostats “cycled” heat pumps, increasing consumption. Prices for HP participants fell over the trial period due to falling wholesale prices. This meant that consumers on the HP tariff experienced bill savings even without changing their consumption This makes it difficult to evaluate the effects of the DSR incentives in the HP trial.
Information and enabling technologies:	Participants with central air conditioning or central electric heating were offered a smart thermostat, which reduces usage when power prices are high. Take-up of the smart thermostat was 33%. Participants were sent an education package consisting of a fridge magnet displaying critical peak hours and contact information, a pricing leaflet, and a conservation brochure. Group meetings were held two weeks before live billing (two hour evening sessions, one for each of the three price plans), which were attended by 20-25% of participants. For some months, participants were sent bill inserts highlighting specific saving opportunities (e.g. holiday lighting, air conditioning, and dehumidifiers). Participants received new bills after the start of the trial, and monthly Electric Usage Reports that showed graphics of daily electricity usage by price.
Consumer take up of DSR tariffs/schemes	The average response rate to recruitment for the programme was 6.6%, and 7.6% for those with limited income. More than 74% of participants were satisfied with the trial, and 6% were dissatisfied. 89% of participants would recommend PowerCentsDC to a friend. More than 93% of participants that responded stated a preference for PowerCentsDC pricing (smart pricing) over default (SOS) pricing. The top motivations for participation were:

Overview	
	• saving money (73%); • reducing emissions (34%); • exploring smart grids (33%); and • assisting policymakers (32%). When ranking the potential benefits of the trial pricing structure, the following reasons received the greatest proportion of top rankings: • the pricing makes the participant more aware of when the household uses electricity during the day/week; • making the participant more conscious of their electricity usage during peak/expensive times; and • giving the participant more control over their electricity costs.
Summary of results	
What behaviours changed?	There were statistically significant average reductions (weighted by the actual population of consumers on each original rate schedule type in the district population) in critical peak electricity demand of: • CPP: 34% in summer, 13% in winter; • CPR: 13% in summer, 5% in winter; and • HP: 4% in summer, 2% in winter. The smaller results for HP participants could be in part due to declining average prices over time for these consumers (due to changing market conditions), and as high prices for these consumers were not as high as the critical peak price and the critical peak rebate. Greater peak demand reductions in summer suggest that consumers have more discretionary load in summer than winter. The main actions taken to reduce peak demand were avoiding using appliances (60% of participants), reducing air conditioning consumption (59%), and turning off lights (44%).

Overview	
	High summer temperatures resulted in larger peak reductions for CPP and CPR participants. Average peak reduction at 29.5ºC was 26% for CPP participants and 8% for CPR participants, compared to 43% and 20% respectively at 36 ºC.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	52% of participants agreed or strongly agreed that Electricity Usage Reports helped them save on their electricity bill. 42% reported that their household significantly changed their electricity usage during critical peak/high price hours after reviewing their electricity usage statements, and 38% slightly changed their usage.
What role did incentives play?	Compared to an average standard offer service bill for the group, CPP consumers saved 2%, CPR consumers saved 5%, and HP consumers saved 39%. Compared to the standard offer service bill, bills were lower for 91% of CPP and CPR consumers, and all HP consumers.
Did complexity matter?	-
How important was automation?	Some consumers had smart thermostats for central air conditioning (which reduce electricity consumption when power prices are high) Average summer critical peak demand reductions were the following: Regular consumers: • CPP: 29% without a smart thermostat, 49% with a smart thermostat; • CPR: 11% without a smart thermostat, 17% with; and • HP: the reduction not statistically significant without a smart

Overview	
	thermostat, 10% with a smart thermostat. For all electric consumers, these reductions were: • CPP: 22% w/o smart thermostat, 51% with • CPR: 6% without a smart thermostat, 24% with a smart thermostat; and • HP: 10% without a smart thermostat, and -2% with a smart thermostat. 29% of CPR participants and 44% of HP and CPP participants overrode the automatic thermostat adjustment during two or more critical peak events.
Did different consumers behave differently?	Low-income consumers (who only participated in the CPR plan) showed a slightly smaller average peak demand reduction, of 11% compared to 13% for regular-income consumers. Renters (who owned fewer appliances than homeowners in some categories, but more electric intensive appliances in others) were found to have more high-intensity electricity usage during peak hours than homeowners—e.g. cooking, baking, watching flat screen TB, and clothes washing/drying.
Are the results consistent over time?	-

Source: Frontier Economics

Table 17. Flex Alert Campaign (2008)

Overview	
Title of study:	2008 Flex Alert Campaign Evaluation Report
Author(s):	Summit Blue Consulting
Date:	December 10 2008
Source:	http://www.calmac.org/publications/2008_Flex_Alert_Final_Report_12-18-08.pdf
Categorisation	
Country/region:	California
Period covered:	July 2008
Sample size:	State-wide
Consumer categorisation:	-
DSR categorisation:	The Flex Alert: Save Energy Now! Campaign used mass media to encourage consumers in California to reduce their electricity consumption on critical days (as determined by the California Independent System Operator, CAISO). The campaign was co-branded with the Flex Your Power campaign, which encourages the use of energy-efficiency appliances and products. The campaign promoted energy saving and shifting actions that consumers could take during peak hours. The top three actions promoted were as follows. • setting air conditioning thermostats to 25.6ºC or above; • switching off unnecessary lighting; and • delaying the use of appliances such as dishwashers until after

Overview	
	the peak (7pm). Information about the Flex Alert was available online (including via the websites of the main electricity companies) and was sent to participants via email. There was also significant TV news coverage of the event (145 stories on the first day, 16 on the third day)
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	N/A
Implications for key questions	
What behaviours changed?	37% of all survey respondents reported taking conservation action(s) in response to the Flex Alert message (whether the recalled message was received via the adverts or media coverage). The estimated reduction in electricity use resulting from the 2008 Flex Alert campaign was 222—282MW, based on self-reported behaviour for air conditioning and lighting. Lighting represented roughly one sixth of the impact.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	**Complexity:** There was low recall of the hours during which energy consumption should be reduced.
What worked to alleviate the barriers?	Focus group respondents emphasised a need to highlight success stories of people taking conservation actions at the neighbourhood level, in order to appeal to community pride. Segmentation was important. Three hypothesised segments

Overview	
	emerging from the 2008 focus group were: “The Choir:” The appropriate message to convey to this group was “Do a little more of what you are already doing,” and the motivation was that the group already appreciate the seriousness of alerts. “Reluctant Converts:” The key message for this group was “Even business and governments are doing their part to prevent blackouts.” The motivation for this group is to overcome resentment and make the seriousness clear by providing data. “Financially Driven Converts:” Their key message was that through conservation they could achieve “Cost savings over time and at the state level,” and the motivation for this group to act was “because you told us to.” (Taken from Table E-2, p.6 of the report)
What role did incentives play?	-
Did complexity matter?	Consumers displayed little understanding of production/supply of electricity, and did not know how the concept of global warming and the creation of electric power were linked. This meant that messages including global warming and short-term blackouts were not understood. Following the event, 67% of survey respondents (both those aided by interviewers and unaided) recalled an energy conservation message or the Flex Alert. Of the respondents that recalled an energy conservation message, less than half understood that conservation was required at certain times of day (3-7pm).
How important was automation?	There was none built into the trial.
Did different consumers behave differently?	Survey respondents in hotter climate zones were both more likely to change their behaviour in response to the Flex Alert, and had a larger average response (0.144 kW compared to 0.070 kW for respondents in cooler climate zones).

Overview	
Are the results consistent over time?	-

Source: Frontier Economics

Table 18. myPower Pricing Segments Trial (2006-2007)

Overview	
Title of study:	Final Report for the myPower Pricing Segments Evaluation
Author(s):	Summit Blue Consulting
Date:	December 21 2007
Source:	http://sites.energetics.com/madri/toolbox/pdfs/pricing/mypower_pricing_final_report_2007.pdf
Categorisation	
Country/region:	New Jersey, USA
Period covered:	July 2006-September 2007
Sample size:	379 on the educate-only strand, 319 on the technology enabled strand, and 450 in a control group.
Consumer categorisation:	20% of myPower participants had income up to $50,000. 23% of myPower Sense and 17% of myPower Connect participants had a highest educational level of high school graduate or lower. 38% of myPower Sense and 39% of myPower Connection survey respondents were aged 65 or over.
DSR categorisation:	Participants were placed on a three period time of use (ToU) tariff with critical peak pricing (CPP). Consumers were notified

Overview	
	of a CPP by phone and/or email one day in advance, and were given information on how to save energy during a peak or critical peak period. Participants were recruited from communities with high predicted penetration of central air conditioners (Cherry Hill and Hamilton Township). Participants could not select their strand. One group (“technology enabled,” on a programme named “myPower Connection”) were given programmable thermostats that could automatically respond to CPP events and ToU tiers. The other group (“educate only,” on a programme named “myPower Sense”) did not receive these. The CPP scheme was designed to be seasonally revenue neutral compared to the standard tariff a residential consumer would receive. Critical peaks were called on days with high energy prices or high expected supply loads.
Incentives for participation:	Participants that received in-home technology were paid $25 for completing a telephone survey before the pilot started. All participants received $75 upon completion of an end of programme survey.
Other relevant features:	-
Information and enabling technologies:	Treatment and control consumers received an interval meter. The smart thermostat received by some participants could manage air conditioning, electric water heating, and in-ground pool pumps. Consumers could programme the smart thermostat over the internet. A pack of educational materials was sent to participants before the programme started, which included a FAQ sheet, a guide to saving energy, a pricing information sheet, and a fridge magnet including the free programme telephone number. Participants could compare their myPower bill with what their bill would have been under the traditional rates online.

Overview	
Consumer take up of DSR tariffs/schemes	The response rate to recruitment was 4%. Results from surveys during and after the pilot indicated the following. • 77% of myPower Connection and 81% of myPower Sense participants would recommend myPower to a friend or relative. • The majority of participants believed programmes like myPower benefited the environment. • 71% of participants believed they saved money on the programme. • The majority of participants became more knowledgeable about reducing energy consumption over the programme. 94% of myPower Sense and 91% of myPower Connection participants stated that the main reason for participating was to save money on their electricity bills, with the 2nd most common reason to conserve energy.
Implications for key questions	
What behaviours changed?	During summer peak periods, percentage reductions in peak electricity demand were: • 21% on normal days and 26% on critical peak days for myPower Connection (direct control) participants; • 3% on normal days and 14% on critical peak days for myPower Sense (no direct control) participants with central air conditioning; and • 6% on normal days and 14% on critical peak days for myPower Sense (no direct control) participants without central air conditioning. A “snap back” effect was observed following peak hours on hot weekdays, where participants increased their usage of air conditioning immediately after peak hours (6pm-7pm) to reduce indoor temperatures. This effect was higher following critical peak events. Peak period demand reductions were smaller during winter

Overview	
	months. Most programme participants reported that they took actions to reduce electricity consumption during CPP events and high price hours. The specific actions taken to reduce consumption were: • not using electric appliances; • setting the thermostat at a higher temperature; and • turning off air conditioning. 85% of myPower Connection participants changed when they did their chores such as laundry and dishwashing.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	**Economic:** On average, participants reported they saved money in the programme, but average expected savings exceeded average realised savings.
Did complexity matter?	Participants found bills understandable and easy to read. The main area of dissatisfaction with the programme was the difficulty of programming the thermostat.
How important was automation?	Peak period demand reductions were higher for consumers with direct control.
Did different consumers behave differently?	-

Overview	
Are the results consistent over time?	-

Source: Frontier Economics

Table 19. Silver Spring/ OG&E Trial (2010)

Overview	
Title of study:	SEDC: Consumer Engagement and Demand Response Case Study OGE: Engaging Consumers for Demand Response
Author(s):	Respectively: Silver Spring Networks and Raab Associates
Date:	October 2011
Source:	*Presentations available at:* http://sedc-coalition.eu/wp-content/uploads/2011/10/SilverSpringsConsumerEngagementandDRCaseStudy.pdf *and* http://www.raabassociates.org/main/roundtable.asp?sel=109
Categorisation	
Country/region:	USA
Period covered:	2010
Sample size:	Over 3,000 consumers
Consumer categorisation:	-
DSR categorisation:	Consumers were placed either on a ToU tariff with a critical peak (ToU-CP), or a variable peak pricing (VPP) tariff with

Overview	
	critical peaks. Various enabling technologies were also provided.
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	All consumers had smart meters. Three technologies were trialled in combination with the tariffs. These were: • Programmable communicating thermostats (PCTs), which were programmed to respond to price changes, and provided current and day-ahead prices. • In-home displays (IHDs), which display real-time energy usage, and provided current and day-ahead prices. • A web portal which provided alerts for peak events, current and day-ahead prices, and recent usage information.
Consumer take up of DSR tariffs/schemes	-
Summary of results	
What behaviours changed?	Average peak electricity demand reductions for the highest price days on the VPP tariff were: • 33% for consumers with the thermostat; • 12% for consumers with the web portal; and • 11% for consumers with the IHD. Peak period energy reductions for these groups were 22%, 8% and 6% respectively for standard price critical peak days on the VPP tariffs. For VPP consumers, the highest peak demand reduction was achieved with the programmable communicating thermostat, while peak demand reductions for consumers with the IHD or

<table>
<tr><th>Overview</th><th></th></tr>
<tr><td></td><td>web portal were smaller but more consistent.

For ToU-CP consumers, peak period energy reductions on non-event weekdays were:

• 30% for consumers with the thermostat;
• 11% for consumers with the portal; and
• 17% for consumers with the IHD.</td></tr>
<tr><td>What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?</td><td>-</td></tr>
<tr><td>What worked to alleviate the barriers?</td><td>-</td></tr>
<tr><td>What role did incentives play?</td><td>Peak demand reduction was highly correlated with price.

98% of all consumers saved money in the trial, although a limited number of critical events were called.</td></tr>
<tr><td>Did complexity matter?</td><td>-</td></tr>
<tr><td>How important was automation?</td><td>Peak period demand reductions were higher for consumers with the smart thermostat than for consumers with an IHD or access to the web portal.</td></tr>
<tr><td>Did different consumers behave differently?</td><td>The results showed that low-income and elderly groups were also able to shift their electricity demand.

On average, peak demand reductions were 20% for low-income consumers, 30% for middle-income consumers, and 37% for high-income consumers.

• However, this differed between technology types. For low (high) income groups, peak period demand reductions were:48% (33%) for consumers with the thermostat;</td></tr>
</table>

Overview	
	• 13% (14%) for consumers with the web portal; and • 5% (14%) for consumers with the IHD. Peak demand reductions were on average 36% for young consumers, 24% for “family” consumers, and 28% for mature consumers (it was not clear how these groups were defined). Again, this differed between technology types, as set out below. • Mature consumers were most responsive to programmable thermostats (40% peak reductions compared to 29% for the young and 32% for families). • Families were most responsive to the web portal (18% peak reductions compared to 15% for the young and 5% for mature consumers). • Mature participants were less responsive to IHDs, with peak demand reductions of 4%, compared to 15% for young and family consumers.
Are the results consistent over time?	-

Source: Frontier Economics

Table 20. EDRP Trials (2007-2010)

Overview	
Title of study:	Energy Demand Research Project: Final Analysis
Author(s):	AECOM Ltd for Ofgem
Date:	June 2011
Source:	Final Analysis at: http://www.ofgem.gov.uk/Sustainability/EDRP/Documents1/Energy%20Demand%20Research%20Project%20Final%20Analysis.pdf And Appendix D at:

Overview	
	http://www.ofgem.gov.uk/Sustainability/EDRP/Documents1/EDRP%20Appendix%20D%20SSE%20community%20trials.pdf
Categorisation	
Country/region:	UK
Period covered:	2007-2010
Sample size:	61,344 overall, of which 18,370 had smart meters. The EDF ToU trial had 194 participants, and 1,352 participants in the SSE trial had the incentive to shift their demand[124]
Consumer categorisation:	-
DSR categorisation:	Time of use (ToU) tariffs combined with smart meters and consumer engagement measures (such as feedback and incentives to reduce consumption).
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	Participants had smart meters installed. Consumers on EdF's ToU tariff had accurate billing, a real-time display, and energy efficiency advice sent by post. Participants on SSE's ToU tariff received some combination of a booklet, monthly bills with graphs, an incentive to reduce consumption, a real-time display, and web information.
Consumer take up of DSR tariffs/schemes	-

124 It is not clear whether all these households were on the ToU tariff, or whether the incentive to shift also included other types of intervention.

Summary of results	
What behaviours changed?	Load shifting away from the peak period was up to 10%. This was greater on weekends than weekdays. In the SSE ToU trial, load shifting away from peak periods was greater for groups without web information and without a real-time display. This could suggest that too many interventions increased complexity, reducing the response.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	**EdF:** Survey results indicated that 38% of consumers in the ToU tariff trial sample were aware of the real-time display in their home, which was the lowest awareness amongst the trial groups in this study. This could be because the real-time display provided to ToU consumers was more basic than that provided to some other groups. Consumers on the ToU tariff also rated the usefulness of the visual display below the ratings given by three of the four other trial groups. (54% of the 24 ToU consumers that answered the question found the visual display quite useful, 25% found it not very useful, and 12.5% found it not at all useful). 65% of survey respondents in the ToU trial sample agreed or strongly agreed that the smart meter technology had enabled them to plan or budget their energy use. This compared to an average across samples of 55% of consumers that agreed or strongly agreed with the statement. **SSE**: Survey data from participants with smart meters (and/or RTDs) in the SSE trial found that the most frequent reason for joining the trial was to save money, and the next most frequent motivation was to help the environment.[125] The energy advice booklet had a high recall rate (80%), and consumers were more likely to say it was quite or very useful, and to still refer to it, if they owned an RTD. Early survey evidence on the recall of additional billing data was low (32% recalled something different about their bills). 60% of respondents without smart meters in the final survey

125 Participants were asked about their motivations for joining more than two years after they decided to participate, so results may not be reliable.

Overview	
	found enhanced billing information quite or very useful, compared to 34% of consumers without smart meters. Use of the website by consumers with smart meters was low, at 9%. Satisfaction with and recall of smart meters was higher for credit and prepayment consumers (who had an RTD) than for consumers without an RTD. Results from an early survey showed that 53% of consumers that had received an RTD had fitted it. Consumers viewed the RTD more frequently than the clip-on device provided to consumers without smart meters. Respondents rated cost information above energy information on RTDs, and the traffic light display was rated the most useful feature. 83% of consumers with the incentive to shift their demand were aware of it, and 75% were aware and had some understanding of the incentive. 40% of consumers aware of the incentive to shift reported that they had shifted their electricity demand and saved money, 33% reported they had shifted their demand but not saved money, and 28% reported that they had not shifted their demand. Consumers without the incentive to shift or reduce demand reported that the night rate would have to be 19-32% cheaper than the peak day rate in order to encourage them to shift their demand.
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	Load shifting in the SSE trial was smaller than for the EDF trial. The report stated that this could have been due to more limited awareness of the intervention and a perception that it was overly complex. SSE's trial found that the load shifting incentive had a greater

Overview	
	effect for consumers without an IHD, which the report suggested could be due to "some kind of interference effect if too many interventions are in effect at the same time."
How important was automation?	There was none built into the trial.
Did different consumers behave differently?	In the EdF trial, load shifting was greater for smaller households (with 1 or 2 people aged 16-64 in the household). The proportion of electricity consumption in peak periods increased with additional household members under the age of 16, with paraffin/oil/no heating compared to electric/gas heating, and was higher for households in South East England.
Are the results consistent over time?	-

Source: Frontier Economics

Table 21. Norway ToU and Direct Control Trial (2001-2004)

Overview	
Title of study:	Energy efficiency and load curve impacts of commercial development in competitive markets, Results from the EFFLOCOM Pilots NB: The information in this table is on one of the DSR studies reported in the paper.
Author(s):	EFFLOCOM
Date:	30th June 2004
Source:	http://www.sintef.no/project/Efflocom/EFFLOCOM%20report%20no.%207%20Pilot%20Results%5b1%5d.pdf
Categorisation	
Country/region:	Norway

Overview	
Period covered:	2001-2004
Sample size:	10,895
Consumer categorisation:	-
DSR categorisation:	Residential consumers were placed on one of three tariffs. • a ToU tariff; • a dynamic tariff with a real-time element depending on the wholesale spot price; and • a dynamic tariff with a temperature dependent part. The variable parts of the dynamic tariffs were only activated in periods of peak load (8-11am and 5-8pm for November-April). For consumers that accepted remote load control, low prioritised loads (Boilers for water heating) could be disconnected by the energy supplier under certain conditions.
Incentives for participation:	Consumers received a payment of €100 for accepting remote load control.
Other relevant features:	-
Information and enabling technologies:	Consumers received smart meters.
Consumer take up of DSR tariffs/schemes	Roughly 50% of consumers accepted remote load control.
Implications for key questions	
What behaviours changed?	Results for Buskerud Kraftnett showed the following. • For consumers with remote load control, there was a 12% reduction in morning peak usage, and a 14% reduction in afternoon peak usage. (1,230 consumers) • For consumers with the ToU tariff but no load control,

Overview	
	maximum peak use reductions were 10% in the morning and 7% in the afternoon. (39 consumers). • Results for the ToU tariff and spot price on an hourly basis showed larger peak reductions, but the sample size was small (six). Results for Skagerak Nett showed the following. • For ToU consumers without load control, the maximum peak period demand reductions were 8% in the morning and 9% in the afternoon (198 consumers) • For consumers with ToU pricing and an hourly spot price, the maximum peak period demand reductions were 14% in the morning and 28% during the afternoon (24 consumers).
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	-
Did different consumers behave differently?	-
Are the results consistent over time?	-

Source: Frontier Economics

Table 22. Northern Ireland Powershift trial (2003-2004)

Overview	
Title of study:	Smart meters in Great Britain: the next steps? Paper 6: Case studies
Author(s):	Gill Owen and Judith Ward
Date:	July 2007
Source:	http://www.sustainabilityfirst.org.uk/docs/2007/Smart%20Meters%20in%20Great%20Britain%20-%20Paper%206%20-%20Case%20Studies%20-%20Sustainability%20First%20-%20July%202007.pdf Here we summarise the review of the Powershift tariff only.
Categorisation	
Country/region:	Northern Ireland
Period covered:	2003-2004
Sample size:	100 keypad (prepayment) consumers on the ToU tariff, and an additional control group of 100 keypad consumers with the flat rate tariff.
Consumer categorisation:	30% of consumers in Northern Ireland used keypad prepayment meters in 2009, of which 58% were low-income consumers. Consumption by Keypad consumers was in general 6.4% lower than average overall average domestic electricity consumption in Northern Ireland in 2005/6.
DSR categorisation:	The trial tested a time-of-use (ToU) tariff with low, medium and high price periods. The hours of operation for these differed between weekdays and weekends. Consumers received a leaflet that advised them to avoid using some appliances during peak hours. It also provided estimates of the cost of using specific appliances (tumble dryer, washing machine, and electric shower) during the different periods

Overview	
	compared to the standard rate. The ToU tariff rates were the following: • Low: 5.76p/kWh • Medium: 8.64p/kWh • High: 15.36p/kWh The flat rate was 9.146p/kWh
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	The tariff was available to prepayment consumers with a Keypad meter with an IHD. The Keypad meter did not have two-way communication. but the display allowed consumers to monitor their current load, tariff rates, the number of units used at each rate, previous costs and remaining credit.
Consumer take up of DSR tariffs/schemes:	The consumer response to Powershift was positive, and in 2007 there were 1000 consumers on the tariff.
Implications for key questions	
What behaviours changed?	Consumers on the ToU tariff experienced lower consumption at peak periods relative to the control group, but their overall usage slightly increased. Bills were reduced for ToU consumers. The average annual bill for consumers on the ToU tariff was £371.98, compared to £393.54 for the control group on the flat tariff. Much of this bill saving appears to have been passive, i.e. was achieved without changing behaviour, as the average annual bill for the control group would have been £377.60 if they had been charged the ToU prices for their use.[126] The percentage of consumption that fell into the high rate

126 P. 24, Sustainability First, 2010, Smart Tariffs and Household Demand Response for Great Britain.

Overview	
	period during the trial was 15% for ToU consumers and 17% for the control group. This compared to 61% (25%) for the medium (low) rate for ToU consumers, and 25% (24%) for the control group.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	There was none built into the trial.
Did different consumers behave differently?	-
Are the results consistent over time?	-

Source: Frontier Economics

Table 23. EcoWatt DSR Programme, Brittany and the Provence-Alps-Côte D'Azur Region

Overview	
Title of study:	Generation Adequacy Report, on the electricity supply-demand balance in France
Author(s):	Réseau de transport d'électricité (Rte)

Overview	
Date:	2011
Source:	http://clients.rte-france.com/htm/an/mediatheque/telecharge/generation_adequacy_report_2011.pdf
Categorisation	
Country/region:	Brittany and the Provence-Alps-Côte D'Azur Region (PACA). .
Period covered:	2008 onwards.
Sample size:	-
Consumer categorisation:	-
DSR categorisation:	EcoWatt provides information on the importance of peak loads and power cut risks, and encourages consumers to reduce their electricity consumption. On critical (high demand) days, consumers were alerted by text or email and asked to reduce their electricity demand. Nine alerts were sent during winter 2008/9.
Incentives for participation:	-
Other relevant features:	The highest demand peaks occur during winter.
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	Over 30,500 consumers had subscribed to EcoWatt at the end of winter 2010/11.
Implications for key questions	

Overview	
What behaviours changed?	Brittany: RTE estimated power demand in Brittany fell by 2.5% during an alert in winter 2010. However, an IPSOS poll in February 2011 showed that, regardless of whether or not they were subscribed to EcoWatt, 78% of individuals said they reduced their demand during alerts.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	There was none built into the trial.
Did different consumers behave differently?	-
Are the results consistent over time?	-

Source: Frontier Economics

Table 24. EdF Tempo tariff

Overview	
Title of study:	Energy efficiency and load curve impacts of commercial development in competitive markets, Results from the EFFLOCOM Pilots NB: The information in this table is on one of the DSR studies

Overview	
	reported in the paper.
Author(s):	EFFLOCOM
Date:	30th June 2004
Source:	http://www.sintef.no/project/Efflocom/EFFLOCOM%20report%20no.%207%20Pilot%20Results%5b1%5d.pdf
Categorisation	
Country/region:	France
Period covered:	1989-1992 (experimental stage), 1993-1995 (tariff launch), and generalisation after 1995.
Sample size:	• Experimental stage: 800 consumers. • For launch (1993 onwards): 20,000 by 1995. • Generalisation: there were more than 300,000 domestic tempo consumers in 2004.
Consumer categorisation:	The paper reported that consumers choosing to be on the tempo tariff were prepared to change their behaviour in order to make small bill savings in relation to their standard of living (so they might be more receptive to economic incentives than other consumers).
DSR categorisation:	The Tempo tariff divides the year into 300 standard price blue days, 43 white days (with a medium price), and 22 red days (with a higher price). Weekend days were always blue. On each day, there are fixed peak and off-peak periods. For launch (1993 onwards), four different combinations were offered: • the standard tempo tariff; • dual energy tempo, for consumers with a dual-energy boiler,

Overview	
	which could switch source automatically depending on the current price; • thermostat tempo which adjusts heating depending on the current price; and • comfort tempo, which manages end uses such as space and water heating and large electric appliances.
Incentive mechanism:	-
Other relevant features:	-
Information and enabling technologies:	For launch (1993 onwards): • EDF developed a notification device which can be plugged into a power socket and displays the colour of the day and the current hourly rating. It also provides advance notification of the colour for the next day from 8pm. • A smart meter displaying the same information as the notification device, as well as the consumption per tariff period. • Energy control systems that enabled consumers to programme their demand (and communicate this to appliances) according to current prices and their specified indoor temperature. • Consumers received information booklets, a start-up visit and advice from a tempo specialist, and could receive a report after one year to set out the billing differences under the tempo tariff.
Consumer take up of DSR tariffs/schemes	Experimental stage: • 84% of consumers were quite or very satisfied with the tariff; • 87% understood the principle very well; • 59% said they had made savings; and • 53% considered the tariff to be slightly restrictive or entirely

Overview	
	unrestrictive.
Implications for key questions	
What behaviours changed?	Experimental stage: The results of the pilot showed that consumption was reduced by 15% on white (medium price) and 45% on red (high price) days. Load shifting from peak to off-peak hours was 1.3 times higher on white than blue days, and higher again for red days. The main consumption reductions on white or red days came from reduced electric heating. Consumers either used fireplaces or accepted a lower temperature.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	Results were not reported for automation.
Did different consumers behave differently?	-
Are the results consistent over time?	Consumption reductions on white and red days were stable over the years.

Source: Frontier Economics

Table 25. Southern California Edison direct control measures (2010)

Overview	
Title of study:	Southern California Edison's (SCE's) 2010 Demand Response Load Impact Evaluations Portfolio Summary
Author(s):	Freeman, Sullivan & Co. (FSC)
Date:	April 1 2011
Source:	http://fscgroup.com/reports/SCE-DR-Portfolio-Summary-2010.pdf
Categorisation	
Country/region:	Southern California, USA
Period covered:	2010
Sample size:	343,566 residential consumers on the summer discount plan
Consumer categorisation:	-
DSR categorisation:	A number of different initiatives were in place, but ex-post results for domestic consumers were only available for the direct control programme (the summer discount plan (SDP)). SCE directly controls air conditioning for residential consumers on the SDP programme. This limits the compressor during high system peak hours, reducing the electricity used by the air conditioning unit. Consumers could choose whether to limit the maximum number of events, and the cycling strategy (i.e. the degree to which their comfort would be affected). The basic plan has a maximum of 15 events per summer, and up to six hours of direct control at a time. The enhanced plan has no limit on the number of direct control events, and higher incentives.
Incentive mechanism:	Economic incentives were used to encourage consumers to allow direct control. Those with a higher number of possible

Overview	
	events had higher rewards.
Other relevant features:	All consumers had air conditioning that could be directly controlled by SCE.
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	The SDP Residential direct control programme resulted in an average reduction in load of 83% for the directly controlled air conditioner per event hour in 2010. (This excluded one half hour event that occurred during a relatively low temperature period.)
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	-
Did different consumers behave differently?	-
Are the results	-

Overview	
consistent over time?	

Source: Frontier Economics

Table 26. Illinois real-time pricing trial

Overview	
Title of study:	Evaluation of the 2006 Energy-Smart Pricing Plan, Final Report
Author(s):	Summit Blue Consulting LLC
Date:	November 2007
Source:	www.cntenergy.org/download/19/
Categorisation	
Country/region:	Illinois, USA
Period covered:	2003-2006
Sample size:	Initially 651 participants (and an additional control group of 103), and approximately 1,500 in 2005.
Consumer categorisation:	-
DSR categorisation:	Real-time pricing based on the day-ahead hourly electricity price. Hourly prices were announced the day before, and consumers were notified when the price exceeded a set threshold. The hourly price was capped.
Incentives for participation:	-
Other relevant features:	-

Overview	
Information and enabling technologies:	57 consumers were provided with air conditioning cycling switches in 2004. Some consumers were provided with an “Energy PriceLight” (an orb relaying information on the level of electricity price by glowing different colours) in 2006. Consumers were provided with usage information on tips on how to reduce peak period and overall electricity usage.
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	Price elasticity of demand for electricity was higher for high prices than low prices. Consumers with the Energy PriceLight had a 2.4% higher price elasticity than consumers without it. The regression analysis showed that demand response to hourly prices above and below the high-price threshold was statistically significant. Consumers saved money on their bills compared to what they would have paid at the alternative (flat rate) tariff in 2003, 2004 and 2006, with average savings of 20.1%, 11.3% and 15.5% respectively. Consumers' bills were higher on the trial tariff than the alternative tariff in 2005, by 6.3%.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-

Overview	
Did complexity matter?	-
How important was automation?	Consumers with automatic air conditioning cycling during high-price periods had a 9.8% higher elasticity of demand.
Did different consumers behave differently?	Elasticity of demand increased as neighbourhood household income fell.
Are the results consistent over time?	-

Source: Frontier Economics

Table 27. Pacific Northwest Gridwise Trial

Overview	
Title of study:	Pacific Northwest GridWise Testbed Demonstration Projects, Part I. Olympic Peninsula Project
Author(s):	Hammerstrom, D.J.
Date:	October 2007
Source:	http://www2.econ.iastate.edu/tesfatsi/OlympicPeninsulaProject.FinalReport_pnnl17167.pdf
Categorisation	
Country/region:	USA
Period covered:	2006-2007
Sample size:	112 households
Consumer	Residential participants were not selected randomly-households were targeted for participation based on their

Overview	
categorisation:	ownership of suitable appliances and high speed internet
DSR categorisation:	Consumers were placed on one of the following tariffs. • Fixed prices; • a CPP tariff that overlaid a static ToU tariff; and • real-time pricing with prices that varied every five minutes. Electric water and space heating were directly controlled for the (~75) consumers on time of day tariffs. Consumers could choose the degree of price responsiveness of their appliances from a list of "comfort settings." Participants could override direct control.
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	Some participants in the trial owned appliances (electric water and space heating) that could be directly controlled.
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	The reduction in peak period demand for consumers on the real-time pricing tariff was 15-17%, compared to 20% for the group on ToU/CPP tariffs[127]
What barriers were identified to moving demand (by category e.g. economic, complexity,	-

127 Faruqui, A. and Sergici, S. (The Brattle Group), 2009, Household Response to Dynamic Pricing of Electricity- A Survey of the Experimental Evidence.

Overview	
housing/appliance, lifestyle)?	
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	-
Did different consumers behave differently?	-
Are the results consistent over time?	-

Table 28. Anaheim Critical Peak Rebate Trial

Overview	
Title of study:	Residential Customer Response to Real-Time Pricing: The Anaheim Critical-Peak Pricing Experiment
Author(s):	Frank A. Wolak
Date:	2006
Source:	http://www.stanford.edu/group/fwolak/cgi-bin/sites/default/files/files/Residential%20Customer%20Response%20to%20Real-Time%20Pricing%2C%20The%20Anaheim%20Critical-Peak%20Pricing%20Experiment_May%202006_Wolak.pdf
Categorisation	

Overview	
Country/region:	Anaheim, USA
Period covered:	June-October 2005
Sample size:	71 on the trial tariff, 52 in a control group. Participants were randomly sampled.
Consumer categorisation:	-
DSR categorisation:	The trial tested a critical peak rebate (CPR) tariff. This consisted of a standard rising block tariff apart from on critical peak days from 12am - 6pm. The critical peak rebate was $0.35 for every kWh reduction in demand during critical peaks relative to average consumption during the peak period on non-critical peak days.
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	The average reduction in electricity demand during critical peak hours was 12% relative to the control group. The average reduction in critical peak demand was greater on critical peak days with higher temperatures.
What barriers were identified to moving demand (by category e.g. economic, complexity,	-

Overview	
housing/appliance, lifestyle)?	
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	-
Did different consumers behave differently?	-
Are the results consistent over time?	-

Table 29. California Automated Demand Response Trial

Overview	
Title of study:	Automated Demand Response System Pilot, Final Report
Author(s):	Rocky Mountain Institute
Date:	March 2006
Source:	http://sites.energetics.com/MADRI/toolbox/pdfs/pricing/ca_automated_dr_sys.pdf
Categorisation	
Country/region:	California, USA
Period covered:	2004-2005

Overview	
Sample size:	122 consumers in 2004, 98 in 2005, and an additional control group of 104 in 2004, and 101 in 2005.
Consumer categorisation:	-
DSR categorisation:	This trial was a subset of the California state-wide trials. Participants in the trial were on the critical peak pricing (CPP) tariff used in the California state-wide pricing pilot. In addition, they received a technology (the GoodWatts system) that enabled them (or energy suppliers) to automate demand response by large single load appliances such as central air conditioning units, pool pumps, or water heating (though the technology was not used on water heating in this trial).
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	For high consumption consumers, average reductions in peak period electricity demand were as follows: • 51% in 2004 and 43% in 2005 for critical peak days; and • 32% in 2004 and 27% in 2005 for non-critical peak days.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-

Overview	
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	-
Did different consumers behave differently?	-
Are the results consistent over time?	-

Table 30. Xcel Energy ToU Trial

Overview	
Title of study:	Household Response to Dynamic Pricing of Electricity- A Survey of the Experimental Evidence
Author(s):	Ahmad Faruqui and Sanem Sergici
Date:	January 2009
Source:	http://www.hks.harvard.edu/hepg/Papers/2009/The%20Power%20of%20Experimentation%20_01-11-09_.pdf
Categorisation	
Country/region:	Colorado, USA
Period covered:	July 2006- July 2007

Overview	
Sample size:	3,700 initial volunteers, and a final sample of 2,900 residential consumers. There may have been some self-selection, as consumers volunteered for the scheme rather than being recruited by a random sample.
Consumer categorisation:	-
DSR categorisation:	Consumers were placed on one of three tariffs: • time of use (ToU); • a critical peak pricing (CPP) tariff; and • a combined ToU and CPP tariff. Consumers were notified of critical peaks a day in advance, and a maximum of 10 critical peaks could be called, all on summer days.
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	Peak period demand reductions were measured during the summer months (June-September). The results were the following. For consumers with central air conditioning peak period demand reductions were: • 5.19% under the ToU tariff;

Overview	
	• 38.42% under the CPP tariff; and • 28.75% under the combined CPP and ToU tariff. For consumers without central air conditioning, peak period demand reductions were: • 10.63% under the ToU tariff; • 31.91% under the CPP tariff; and • 15.12% under the combined ToU and CPP tariff.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	Peak period demand reductions were greater for consumers with automating technologies: • 44.81% for consumers on the CPP tariff with an air conditioning cycling switch; • 46.86% for consumers on the ToU-CPP tariff with an air conditioning cycling switch; and • 54.22% for consumers on the ToU-CPP tariff with a programmable thermostat. The meters used in the pilot were considered too expensive to make the measures trialled cost-effective, and the results of the pilot were considered "as a proof of concept rather than a

Overview	
	technology test."[128]
Did different consumers behave differently?	-
Are the results consistent over time?	-

Table 31. Florida Gulf Power Select Programme

Overview	
Title of study:	Appendix B. Gulf Power's Residential Service Variable Price Option, in Dynamic Pricing, Advanced Metering and Demand Response in Electricity Markets, Paper CSEMWP105 (The appendix was compiled using Levy Associates, Principal Investigator, R. Levy and Plexus Research, Inc, Project Investigators, R. Abbott and S. Hadden. New Principles for Demand Response Planning, Electric Power Research Institute (EPRI). EP-P6035/C3047; March 2002.)
Author(s):	Severin Borenstein, Michale Jaske, and Arthur Rosenfeld, Center for the Study of Energy Markets
Date:	October 2002
Source:	Available at http://sites.energetics.com/MADRI/toolbox/pdfs/vision/dynamic_pricing.pdf
Categorisation	
Country/region:	Florida, USA

128 P.20, Faruqui and Sergici (2009)

Overview	
Period covered:	2000 onwards
Sample size:	2,300 residential consumers were on the CPP tariff by the end of 2001.
Consumer categorisation:	-
DSR categorisation:	Consumers were offered the following two DSR tariffs. • A time of use (ToU) tariff with two periods. • A critical peak pricing (CPP) tariff with three periods. These two tariffs were offered alongside the standard flat rate tariff.
Incentives for participation:	Consumers on the CPP tariff were charged a monthly participation fee.
Other relevant features:	-
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	The average reduction in critical peak period demand for consumers on the CPP tariff was 41%, and 22% for non-critical peak periods. Base peak demand was 6.1kW, the average demand reduction during the high price period was 2.1kW per household, and the average critical peak demand reduction was 2.75kW.
What barriers were identified to moving demand (by category e.g. economic,	-

Overview	
complexity, housing/appliance, lifestyle)?	
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	-
Did different consumers behave differently?	-
Are the results consistent over time?	-

Table 32. Idaho DSR trial

Overview	
Title of study:	Household Response to Dynamic Pricing of Electricity- A Survey of the Experimental Evidence and 2007 Energy Watch and Time-of-Day Programs Annual Report
Author(s):	Respectively: Ahmad Faruqui and Sanem Sergici and Idaho Power

Overview	
Date:	January 2009 and February 2008
Source:	http://www.hks.harvard.edu/hepg/Papers/2009/The%20Power%20of%20Experimentation%20_01-11-09_.pdf and http://sites.energetics.com/MADRI/toolbox/pdfs/pricing/idaho_power_ami_pilots.pdf
Categorisation	
Country/region:	Idaho, USA
Period covered:	2005-2006
Sample size:	85 consumers on the ToU tariff, and an additional control group of 420 residential consumers. 68 consumers on the CPP tariff, and an additional control group of 355 consumers.
Consumer categorisation:	-
DSR categorisation:	The trial consisted of the following two strands. • a three period (time of use) ToU tariff; and • a (critical peak pricing) CPP tariff. Consumers on the CPP tariff were notified a day in advance, and critical peaks prices were applied from 5pm-9pm on critical peak days.

Overview	
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	The percentage of electricity use during each of the tariff periods (on-peak, mid-peak and off-peak) was the same for the group on the ToU tariff and the control group during summer 2006. The authors suggest this could be because of the low peak to off-peak price ratio, of approximately 1.84. For consumers on the CPP tariff, the average hourly reduction in electricity demand during critical peaks was 1.26kW (5.03 for the total four-hour critical peak). The range of average hourly reductions in demand across critical peak days was 0.64kW-1.70kW.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-

Overview	
How important was automation?	-
Did different consumers behave differently?	-
Are the results consistent over time?	For consumers on the ToU tariff, there was an increase in the proportion of electricity used during the on-peak period and a decrease in the proportion used in the off-peak period between June-August 2006 and June-August 2007. This could suggest a reduction in demand shifting effects over time.

Table 33. Missouri CPP trial

Overview	
Title of study:	Ameren UE Residential ToU Pilot Study, Load Research Analysis - 2005 Program Results and AmerenUE Residential ToU Pilot Study, Load Research Analysis First Look Results
Author(s):	Both RLW Analytics for Corporate Planning AmerenUE
Date:	Respectively: June 2006 and February 2004
Source:	http://sites.energetics.com/MADRI/toolbox/pdfs/pricing/res_tou_pilot.pdf and http://www.ontarioenergyboard.ca/documents/cases/RP-2004-0203/2005-07-

Overview	
	submissions/cdm_trccomments_toronto_supplementary2.pdf
Categorisation	
Country/region:	Missouri, USA
Period covered:	2004-2005
Sample size:	2004: 91 residential consumers on the ToU rate, 87 on the CPP rate without a smart thermostat, 78 on the CPP rate with a smart thermostat and an additional control group of 297 consumers. 2005: The ToU trial was discontinued, and the CPP and control group samples were increased.
Consumer categorisation:	-
DSR categorisation:	The trial consisted of the following two DSR tariffs. • a time of use (ToU) tariff with three periods; and • a combined ToU and critical peak pricing (CPP) tariff. Some consumers on the CPP tariff also received a smart thermostat.
Incentives for participation:	-
Other relevant features:	-
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	

Overview	
What behaviours changed?	2004 results: There was no statistically significant shift of non-critical peak period electricity demand to mid or off-peak periods for consumers on the ToU tariff and the CPP tariff relative to the control group. The ToU tariff with no critical peak component was dropped from the study following this result, so there were no results for this group in 2005. For consumers on the CPP tariff, average demand fell by 12% during critical peak periods relative to the control group (statistically significant at the 5% level). For consumers with the smart thermostat on the CPP tariff, average demand during critical peak periods fell by 35% relative to the control group (statistically significant at the 5% level). 2005 results: There was an average reduction in critical peak electricity demand of 13% for CPP consumers and 23.5% for CPP consumers with smart thermostats (both statistically significant).
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	-

Overview	
Did different consumers behave differently?	-
Are the results consistent over time?	The proportion of total electricity demand during critical peak periods was lower in 2005 than 2004 for CPP participants without the programmable thermostat, and this was statistically significant. CPP participants with the smart thermostat also showed a reduction in the proportion of electricity demand in critical peak periods between 2004 and 2005, but this was not statistically significant.

Table 34. PSE's ToU trial

Overview	
Title of study:	Demise of PSE's ToU Program imparts lessons
Author(s):	Ahmad Faruqui and Stephen S. George
Date:	2003
Source:	Electric Light & Power Vol. 81.01:14-15, http://www.elp.com/index/display/article-display/165800/articles/electric-light-power/volume-81/issue-1/features/demise-of-pses-tou-program-imparts-lessons.html
Categorisation	
Country/region:	Washington, USA
Period covered:	2001-2002
Sample size:	300,000 residential and small commercial consumers
Consumer categorisation:	-

Overview	
DSR categorisation:	Consumers were placed on a time of use (ToU) tariff with four periods.
Incentives for participation:	Consumers were able to return to the standard tariff if they were dissatisfied with the ToU tariff. In 2002, a $1 per month meter-reading fee was introduced.
Other relevant features:	-
Information and enabling technologies:	-
Consumer take up of DSR tariffs/schemes	-
Implications for key questions	
What behaviours changed?	Peak demand fell by 5% (averaged across months), with higher peak period demand reductions in winter, and lower reductions in summer. Roughly 55% of consumers experienced lower bills in the first year of the trial. After the introduction of the meter-reading fee, 94% of consumers paid $0.80 extra per month (the meter reading fee minus $0.20 in electricity use savings) on the ToU tariff. The ToU tariff was discontinued due to low satisfaction and negative media coverage in its second year.
What barriers were identified to moving demand (by category e.g. economic, complexity, housing/appliance, lifestyle)?	-
What worked to alleviate the barriers?	-

Overview	
What role did incentives play?	-
Did complexity matter?	-
How important was automation?	-
Did different consumers behave differently?	-
Are the results consistent over time?	-

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