Sustainability *first*

Smart Tariffs and Household Demand Response for Great Britain

Gill Owen and Judith Ward

March 2010

Published by Sustainability First

Sponsored by Centrica, EdF Energy, E.ON UK, Onstream, National Grid, Consumer Focus, Energy Saving Trust, National Energy Action, Landis & Gyr, PRI, The Brattle Group, and Ofgem.

Sustainability *First*

Sustainability *First* was set up to develop new approaches to sustainability. Its primary focus is on policy and solutions within the UK, but draws on experiences and initiatives both within and outside the UK.

Sustainability *First* develops implementable ideas in a number of key policy areas – notably, energy, water and waste - where it can make a difference. It undertakes research; publishes policy and discussion papers; organises high level seminars and other events. Sustainability First is a registered charity.

Sustainability First is a registered charity number 1078994

Sustainability First
c/o CHPA
Grosvenor Gardens House
35-37 Grosvenor Gardens
London SW1W 0BS

www.sustainabilityfirst.org.uk

E mail info@sustainabilityfirst.org.uk

Acknowledgements

We would like to thank our group of sponsors both for their financial support and their contributions of information and comments on drafts. We are particularly grateful to The Brattle Group for the high level modelling they undertook for this report. Thanks also to our sponsors for participation and debate at our sponsor meetings, including to colleagues from DECC who attended as observers. Thanks are also due to the trustees of Sustainability First for their support. In addition we wish to thank all those who gave up time during the research phase and also those who provided us with information and comments. Responsibility for the findings, conclusions and recommendations in this paper rests with us.

Gill Owen and Judith Ward.

Gill Owen

Gill Owen is an energy policy consultant and Senior Research Fellow at Warwick Business School. She chairs the Public Utilities Access Forum, is a Non Executive Director of Ofwat, is Deputy Chair of the Government's Fuel Poverty Advisory Group and a member of the Ofgem Smart Meter Consumer Advisory and Social Action Plan Review Groups. She is a former member of the Competition Commission and former non-executive member of Ofgem's board. She has a PhD in energy policy.

E mail : gill.owen1@ntlworld.com

Judith Ward

Judith Ward is an energy policy specialist, an Honorary Fellow at the University of Exeter and Associate Fellow at Warwick Business School. She is an adviser to the UK Business Council for Sustainable Energy and board member of the Institute for European Environment Policy. She spent fourteen years with National Grid until 2004, where her last role was Group Head of Public Affairs. Her early career was spent, inter alia, in policy roles with the House of Commons Environment Select Committee and the national Electricity Consumers' Council. She has a master's degree in Energy Resources Management.

E mail : judithward33@hotmail.com

Smart Meter Research for Sustainability First by Gill Owen and Judith Ward

Gill Owen and Judith Ward are widely published on policy relating to GB household smart meters. Their published reports and working papers available from the Sustainability First website include :

Smart Meters: Commercial, Policy and Regulatory Drivers. March 2006

Smart Meters in Great Britain: the next steps ? July 2007

International Smart Meter Trials. Selected Case Studies. Tariffs and Customer Stimuli (with Engage Consulting). May 2008

The Consumer Implications of Smart Meters. A report for the National Consumer Council. July 2008.

Smart Tariffs and Household Demand Response for GB. March 2010.

Smart Pre-Payment in Great Britain. March 2010.

CONTENTS

PART II – SMART TARIFFS - DELIVERING PUBLIC POLICY, ECONOMIC AND COMMERCIAL BENEFITS

Annexes

Introduction

The Climate Change Act 2008 commits the UK to achieving at least an 80% reduction in greenhouse gas emissions by 2050, compared to 1990 levels. To drive the transition to a low carbon economy the Government has put in place a set of five year carbon budgets to 2022 and set out action plans to achieve the targets set within those budgets.[1] For the household sector, this includes a plan to cut emissions from homes by 29% by 2020 (compared to 2008 levels). Measures to achieve the household sector goals include the Carbon Emissions Reduction Target, the Community Energy Saving Programme, feed-in tariffs for microgeneration, the Renewable Heat Incentive, Warm Front, smart meters and in-home displays. Within the plan there is an increasing emphasis not just on installing energy savings measures and low carbon energy sources but also on developing a greater response from households and other energy users to reduce demand for energy overall and at times of higher prices. Such demand response could help to meet carbon, security of supply and economic objectives.

The Government has decided that all homes should have gas and electricity smart meters by 2020. In December 2009 it also decided on its preferred delivery model – central communications with competitive meter roll-out. The GB Meter Impact Assessment[2] identifies energy savings as the largest economic value in the overall analysis of benefits from smart meters. This is assumed to be largely via improved awareness and feedback, but some of the savings are also assumed to come from new time of use tariffs.

In time, the roll-out of smart meters will allow universal and accurate recording of how much gas or electricity is used by individuals – and when. This will facilitate differential charging – either by time of use and / or by volume. New forms of retail tariff – smart tariffs – might therefore be offered to customers to encourage a demand response.

This report looks ahead to the time when household smart meters will be widespread and thus new tariffs and price incentives might be offered more widely. [*] It examines some of the main issues of principle and practicality likely to arise in introducing new smart-tariffs for households, from both a consumer and market-actor point of view, as well as likely implications for public policy. The report deals with tariffs designed to shift or reduce demand only. It does not cover social tariffs or tariffs for microgeneration. The report is in two parts :

- **Part I** considers the implications for consumers of new retail tariffs facilitated by smart meters.
- **Part II** considers wider public policy, commercial incentives and regulatory issues, likely to arise from future development of GB household demand response. It includes some high level modeling work carried out by The Brattle Group for this study.

[*] Three earlier reports by Sustainability First have examined in depth a range of household smart meter issues, including the consumer implications of implementing a GB smart-meter roll-out.

Executive Summary

The roll-out of smart meters will open the door on differential charging – either by time of use and / or by volume. This report explores the potential for new GB household tariffs and what impacts they might have on : economic and system savings; carbon reduction; companies in the energy supply chain; and consumers.

Today most customers pay for gas and electricity on either a standing charge tariff; or a two-tier tariff (a higher rate for the first block of units and a second lower rate for all further units.) There is also a successful history of simple time-of-use off-peak electricity tariffs for UK households (e.g. Economy 7). Smart tariffs used in other countries have been mainly time-of-use (including critical peak pricing), designed to reduce peak demand for electricity, to help improve security of supply or to reduce the investment costs of meeting peak demand . There has been far less use of energy saving or overall demand reduction tariffs, such as rising block tariffs and so far there have been no trials of smart tariffs for gas, although Ireland is considering one.

There are two main types of smart tariff – **either to reduce peak or to shift load** (e.g. time of use (ToU); critical peak pricing (CPP) ; load control / maximum demand / real time pricing (ie for load-shifting or following)) ; **or, to reduce overall demand** (e.g. rising block; overall load reduction incentives / rewards). Within these two broad tariff types there are many possibilities for tariff design.

Household electricity and gas use – and price responsiveness

Gas currently dominates GB space and water heating - around 80% - but demand is largely saturated and possibly starting to decline due to more efficient boilers, better controls and improved insulation. Household gas customers reduced their use by 12% overall from 2005 to 2007 in response to higher prices. However, in 2008, when the winter was colder, household gas use rose by 3%, despite prices rising in real-terms. There therefore appears to be some available price-response for household gas, but people will understandably choose extra heat rather save money if the weather is very cold .

Around 30 % of household electricity is consumed by electric space-heating and cooking and around 70% by appliances including lighting. Only around 5 % of UK space heating is electric and much of this is off-peak storage heating. Real price increases for electricity between 2005 and 2007 suggested a modest demand reduction in 2007. In 2008, despite real price increases, demand for domestic electricity rose by 2.4%. Around one-fifth to one quarter of household electrical appliance load could be 'discretionary' or price responsive – mainly wet appliances. Very significant new household electrical load from cars and from heat is likely only well into the 2020s, although there will be some new load from heat and cars before this.

Household demand response – carbon and security of supply impacts

Carbon-savings from reduced household electricity-use (peak or load-shift, or overall demand reduction) will not be 'additional' given that power sector carbon emissions are already capped upstream under the EU ETS. There will however be an economic benefit to the UK from purchase of fewer EUAs (carbon emissions permits). Furthermore, the carbon issue for electricity becomes less central in the 2020s as the electricity system decarbonises. 60 % of household carbon emissions are attributed to domestic boilers, so reducing household gas consumption is likely to be the most effective way to reduce these emissions. This will also deliver 'additional' carbon savings, because gas end-use is not capped in the EU ETS.

Household demand response could reduce the need for investment in new generation or network capacity for a given level of security of supply, or could increase security of supply for a given level of investment. To avoid possible double-counting, therefore, we consider the security of supply benefits as potential reductions in costs.

Gas and electricity supply chain impacts – cost savings

- Wholesale energy (capital and operating costs of production, generation and storage) - is the greatest part of the household bill (~50-60%) so savings (operational costs and avoided or deferred capital costs) could be significant. Some benefits could accrue pre-2020 although they would be more substantial post-2020 .
- Network costs (Transmission & Distribution) - form the next biggest portion of the household bill (~20%). Potential peak-cost savings (deferred / avoided costs of investment) are most likely post-2020, if responsive electricity demand grows significantly (heating, vehicles). Significant location-specific cost-savings could be available. There are very limited cost savings available to gas networks from demand reduction.
- System operator costs are a relatively small proportion of the overall bill, but demand-side flexibility, especially location-specific, is likely to be more valuable by the 2020s due to increased nuclear (inflexible) and wind (intermittent).
- Lower household electricity and gas-use could reduce the costs of meeting environmental obligations such as the EU ETS, the Renewables Obligation, and, possibly, the forthcoming Renewable Heat Incentive and CCS levy).

In the 2020s there will be significant economic value from flexibility in the electricity system (i.e. high-priced periods – either at peak or when low or no-wind). Households could contribute to this flexibility requirement if there are significant volumes of new responsive load (potentially refrigeration, electric cars, water heating and electric heat with automated switching and / or with a storage capability).

The Table on the next page summarises high-level results of modelling carried out for this study by the Brattle Group, to show the estimated economic and carbon potential from GB household demand response to 2030.

Estimated Economic and Carbon Potential from Household Demand Response to 2030 (Source – Brattle Group)				
Effect	**Results**		**2010 – 2020**	**2021 – 2030**
Electricity Demand Reduction	Customer Benefits	£ million PV	520-1,400	1,000-2,650
	CO2 Savings	Mt CO2	5-16 MtCO2	7-18 MtCO2
		£ million PV	115-370	150-430
Electricity ToU Tariffs / Load Shifting	Customer Benefits	£ million PV	<130	<270
	CO2 Savings	Mt CO2	0.4-1.7 MtCO2	0.4-1.8 MtCO2
		£ million PV	9-40	10-45
Gas Demand Reductions	Customer Benefits	£ million PV	450-1,350	700-2,150
	CO2 Savings	Mt CO2	4-13 MtCO2	8-24 MtCO2
		£ million PV	180-545	300-890
Fuel Switching (Electric cars; and oil to heat pumps)	Customer Benefits	£ million PV	140-400	1,100-4,000
	CO2 Savings	Mt CO2	0.5-1.0 MtCO2	3-22 MtCO2
		£ million PV	<30	60-525

Note to table : carbon savings from electricity are not additional, due to the EU ETS cap, but do have an economic value (as noted earlier)

The potential role for smart tariffs and impacts on consumers

Which customers gain and which lose will vary according to their individual usage needs and tariff types and their design. For example :

- Electricity peak reduction tariffs (e.g time of use tariffs) could help reduce generation, network and system operation costs. Experience (Northern Ireland, Australia, and US) suggests that a large proportion of consumers on peak tariffs save money even if they do not use less energy overall. GB customers most likely to see such savings are those who can shift their time of use and / or anyway use most electricity off-peak (notably washing machines, dishwashers and tumble driers). However, low income households with on-peak electric heating may be the main group who could be disadvantaged. Available bill savings may be modest now but likely to increase in the 2020s if households take up electric heating and cars.

- An electricity tariff which incentivised less electricity use overall (eg increasing block tariff) would reduce electricity wholesale costs but, without a time-of-use price message, would give no incentive to avoid usage at high-cost periods. Therefore, customers could use less electricity overall but not reduce (or could even add to) costs for generation, networks and system operation. Customers would see savings on their electricity bills if they reduce their electricity-use over a fixed time-period (say, monthly, annual). Tariffs designed to reduce overall consumption would disadvantage high consuming low income households (e.g. large families and those in properties which are expensive to heat). However, there may be ways to compensate these households (cash and/or energy efficiency measures) if they are few in number.

- Tariffs that incentivised reductions in peak demand for gas 'within-day' (eg daily time-of-use) would not reflect current gas market commercial arrangements for a daily balancing price, but other forms of peak gas tariff may be worth exploring for system efficiency reasons (eg weekend, weekday). Tariffs to reduce demand at seasonal peaks (winter) would be cost reflective, but there would be concerns about underheating, fairness and distributional impacts.

- Tariffs that incentivised reduced overall gas use could reduce gas purchase costs for suppliers and shippers. These tariffs would benefit households who are low users or who can reduce their demand, e.g. turning down thermostats, or having their heating on for shorter periods; or who can invest in better controls, new efficient boiler, and improved insulation. Consumers who cannot or do not respond in these ways could however, end up paying more and there are potential concerns for under-heating amongst low income and vulnerable households.

The actual range of tariffs offered by suppliers to customers could be much wider than these four broad types. New tariffs might include :

- Lifestyle tariffs – e.g. time-of-use tariffs to suit those at home all day; or lower prices at evenings and weekends . EDF already offers the non-smart Eco 20:20 tariff, for example.
- Pricing plans – a fixed price for consumption up to x kWh per month, but a relatively high unit charge for consumption above that limit. Could be sold alongside energy saving measures to help customers keep their consumption within the bundled amount. In effect these could be a form of voluntary rising block tariff that could be compatible with a competitive market.
- Energy saving tariffs. Packages could include energy saving measures and financial or other incentives for reduced consumption. SSE's non-smart Better Plan is an example.
- DSM (demand side management) offers. Customers willing to let their supplier automatically control certain appliances could be offered a price incentive to reduce demand briefly at peak or other high-priced periods. These offers may develop for those with electric heating or electric cars.
- Real-time pricing would closely track marginal wholesale costs. RTP is generally considered too complex for small electricity users, but there are some examples in the United States. These types of tariff may become more likely, closer to or post-2020, when continuous automated switching of load could be valuable in a high-wind system.

Rising block tariffs would almost certainly have to be introduced on a mandatory universal basis as otherwise only those who would save money would opt for them which would mean that these tariffs would quickly become uneconomic for suppliers. In effect this would imply re-regulating prices. However, as noted in the list above, there are other forms of energy demand reduction tariffs that could be introduced. Research for the Climate Change Committee concluded that the only rising block tariffs that could benefit the fuel poor would be those applied to electricity consumption in households without electric heating and that therefore "as a method of mitigating against the rise in fuel poverty RBTs would appear to have limited potential".

As an alternative to rising block tariffs for the whole bill, one option for serious consideration might be to apply the rising block principle just to the environmental costs – i.e. Renewables Obligation, EU ETS, CERT, and future schemes such as Renewable Heat Incentive, Feed in Tariffs and the proposed levy for Carbon Capture and Storage. The charges could be related to use – so high users paid more and could be broadly progressive (except for low-income inflexible high-users). Although there would be a rationale for doing so, this would not be straightforward, because of the way some of the charges are structured. There would also be a number of important fairness and distributional issues to consider – particularly as so many low income households live in properties that are difficult or expensive to heat.

Incentives for energy market actors to offer smart tariffs

Incentives for introducing new smart tariffs will vary for different market actors – suppliers, networks, producers, system operators, third parties (aggregators, ESCOs), due to commercial relationships and regulatory treatment. Some may have little incentive to deliver cost-savings to the overall energy system where the benefit may largely fall to others or impose a new cost on them. Integrated suppliers, generators and shippers may be better placed to capture benefits of demand response than stand-alone generators or shippers.

Suppliers are likely to find it easier to realise savings on power or gas procurement and deferred or avoided capacity investment (peaking plant, storage) - which are more under direct supplier control - than to realise savings from network charges. The recently concluded distribution price control review (DPCR 5) has begun the process of neutralising incentives for networks as between new investment in peak-assets against taking more innovative demand-side actions. However, for network cost savings from demand response to translate quickly into reduced network charges for suppliers, it is probable that further evolution may be needed in due course. Emerging thinking with respect to crediting 'negawatts' in distribution use of system charges for embedded generators may perhaps point the way. Furthermore, under present profiled settlement arrangements, the financial benefits of demand-side savings created by an individual supplier (ie cost-savings in production or distribution) may be spread equally among all suppliers and thus act as a disincentive.

Demand reductions (either peak or overall) will need to be firm for suppliers to ensure that either network or procurement costs can be avoided. This will almost certainly require supplier control – such as automatic load control (or an enforceable contract e.g, with an aggregator/ESCO). Aggregation may be necessary to avoid millions of household-level agreements, of small value with high transaction costs. Suppliers may aggregate themselves, or look to third parties. New third-parties could deliver household demand-response for suppliers, networks and system operators but cost-savings would need to be fairly material for there to be enough benefits to share and contractual arrangements would need clarifying.

Recommendations

The recommendations split into three areas : consumer protection; commercial and regulatory issues; public policy benefits.

Smart tariffs offer the potential for some significant consumer benefits but there are some important issues to address.

- Ofgem, DECC and consumer organisations need to continue to develop their general understanding about potential winners and losers and 'fairness' issues from possible new tariffs and pricing plans. Particular attention needs to be given to low income and vulnerable households.

- Smart tariffs will be (and should be) optional for consumers. Ofgem and suppliers need to explore terms and potentially punitive arrangements to avoid 'lock-in' to unsuitable tariffs and ensure that consumers have enough information to make appropriate choices.

- Suppliers need to work with consumer groups and the regulator to avoid over complexity in the range of tariffs they offer. Ofgem should review whether a licence condition on cost reflectivity and/or transparency for new tariffs is needed.

- In the smart meter implementation plan, Ofgem should review conditions governing energy companies' sales and marketing practices, to identify any needs for changes or for strengthening, as some new tariffs may be offered to customers as part of the roll- out of smart meters.

- Suppliers should work in partnership with consumer groups and local energy delivery agenices (e.g Warm Front, Warm Zones) to test the impact of new tariffs and pricing structures on vulnerable and low income groups.

- Consumers will need good feedback (e.g. displays) to benefit from smart tariffs – in particular to know when price periods or price blocks change.

- Consumers will need to be able to access their energy consumption data, to make comparisons between tariffs and switch to the best deal for them. There will therefore need to be agreement on comparability of consumption data – a role for Ofgem working with consumer groups and suppliers. Steps to ensure that customers can review and compare their energy consumption data, will need to tie back to current technical discussions on data formats for meter interoperability and functionality.

There are a number of commercial and regulatory barriers which will need to be addressed by DECC, Ofgem, and the energy companies before smart tariffs can realise household demand response at scale. Incentives will need to align better.

- This paper has shown that there is a strong need for projects under the Low Carbon Networks Fund and under the Innovation Funding Incentive under the distribution price control to test prospective commercial and contractual arrangements and customer incentives for demand response. These funds should therefore not simply bring forward technical trials. DNOs and their partners (suppliers and / or others) should explore and develop projects which will fully test commercial and contractual aspects, including the impacts of new tariffs on customers, suppliers, networks, generators, shippers, and third parties. Ofgem should consider such projects a priority. Non-commercial findings from LCNF and IFI projects should be made generally available so that lessons are shared.

- The industry, as parties to the statutory Distribution Level Codes should consider the need for changes to Network Connection Agreements and to Distribution Use of System Charges to make them more responsive to demand-side actions. Ofgem will also need to engage actively, including ensuring that demand-side actions are enabled as part of the smart meter implementation plans and the proposed new Smart Energy Code.

- Similarly, as parties to the statutory arrangements and Codes for Settlement, the industry will wish to consider the need for change – including the present deemed profile arrangements - to enable suppliers to capture more readily the full economic benefit of any demand-side investment they make for their customers. Again, Ofgem will wish to ensure appropriate links to smart meter implementation plans and proposed new Smart Energy Code.

The potential public policy benefits from new smart-meter tariffs and price packages are only likely to realised in the context of a wider integrated strategy for the household sector.

- Given that much of the very substantial demand-side investment (including micro-generation and renewable heat) as well as the smart meter roll-out will ultimately be funded by customers, DECC, supported by Ofgem, should make sure through good programme coordination, that the various incentive schemes are actively brought together in such a way that the 'whole' in the end adds up to be more than the sum of its parts.

- In developing the smart meter implementation plan, DECC and Ofgem should identify how best, in due course, to judge success in delivery of the public policy aspects of the smart meter roll-out.

- Detailed findings from DECC's Energy Demand Research Project (EDRP) should be made available as soon as possible to inform the development and design of tariffs. DECC and Ofgem should aim to maintain an overview of GB smart meter pilots and trials (EDRP or not) and encourage sharing of non-commercial findings. DECC should consider using their UK energy statistical data to undertake an analysis for Energy Trends of the historical relationship between GB energy retail prices and weather-corrected household gas and electricity demand, including regional differences.

- DECC should commission further work on applying a rising block principle to the environmental costs of energy bills, especially given the scale by which this part of the customer bill is likely to rise by 2020.

Conclusions

Smart tariffs and other price incentives for households, could contribute to delivery of energy bill savings to consumers, economic benefits across the energy supply chain and the public policy goals of carbon emissions reductions and security of supply, but there are many consumer and cross-industry issues to consider. Consumers will judge smart tariffs on the impacts on energy bills, comparability of tariffs and avoiding undue complexity. Some new consumer protection measures are likely to be needed.

For the foreseeable future, reducing household gas consumption (through better insulation, heating controls, upgrading inefficient boilers and encouraging behavioural change) is likely to be the most effective way of reducing household carbon emissions. Price signals, tariffs and improved feedback will have a part to play in behaviour change, but the physical measures will need to be in place to make energy saving a practical and sustainable reality. It is crucially important that these physical improvements are made as soon as possible in the homes of vulnerable and low income consumers. This should be a key issue for the Home Energy Management Strategy, as well as developing measures for able-to-pay households.

At present both the economic value of electricity demand-side flexibility and scope in the household sector for demand response may be rather modest, and as this report shows, there are many steps to be taken to realise even this modest potential. Further, many of these practical issues need to be addressed now in order to facilitate longer-term realisation of the potential economic benefits of household demand flexibility if in due course there is significant take-up of electric cars and new forms of electric heating (assuming storage for the latter). From a customer point of view, the transition to electric cars and heat is only likely to be affordable if these appliances can be mostly charged at low price periods - and so household automation and load-switching will be essential. This will also eventually tie into smarter network development.

PART I

CONSUMERS AND SMART RETAIL TARIFFS

1. Household demand response, tariff types and issues for GB tariff design

1.1 Defining household demand response and smart tariffs

In this report we use the following three terms to describe a customer response to a price stimulus which can result either in a change in the time when energy is used, or, which leads to a reduction in the use of energy overall.

- **Household demand response** – to describe a household action which either shifts and / or reduces overall energy use in response to a price signal or other price stimulus.
- **Peak-shift / load-switch** – a change in time of when energy is used (most likely electricity).
- **Overall demand reduction** – use of less gas or electricity overall .

Household demand response can be secured in a number of ways including through the following kinds of retail price-incentives and rewards :

- Time-varying prices – i.e. charging higher prices at times when it is very cost-beneficial to reduce customer demand (e.g. to reduce the costs of power or fuel-purchase, network or other system costs) and charging lower prices at times when demand-curtailment offers lower system savings.
- Price incentives to reduce demand overall – e.g. rising block tariffs or rewards for reducing demand over a certain period (e.g. a month, season, a year)
- Rewards or discounts linked to automated load control – remote control of certain appliances to switch them on and off at high or low-priced times as required to reduce or to reinstate demand

Households in turn could respond to such price-stimuli in the following ways :

- Delay when they use the energy – but use it later
- Switch off appliances, turn down thermostats (manually or automated)
- Switch to another fuel, or, to on-site energy production – eg switch to on-site heat or electricity production (microgeneration) at high priced times of day

"Smart tariffs" is used in this report as a generic term for a range of tariffs that might be used to induce the forms of household demand response outlined above, most likely in conjunction with a smart meter but also, potentially, without a smart meter but with automated load-control.

1.2 Types of tariff today in Great Britain

Today in GB, for most standard household electricity and gas tariffs, costs are averaged across a customer group and charged at a flat unit-rate regardless of time-of-day or time-of-year. There are currently two main types of standard household tariff in GB :

- Standing-charge tariffs - a daily charge (to recover fixed costs) and a uniform price per unit of electricity or gas consumed. For households with average consumption, the average standing charge accounts for 12 percent (£54.35) of the annual electricity bill and eight percent (£60.41) of the annual gas bill[3].

- Two-tier tariffs – which do not have fixed standing charges. Instead they include a higher unit price on the first tier or block of consumption of electricity or gas (to recover fixed costs). Consumption above the level of the first consumption block is charged at a lower per unit rate. For households with average consumption, the first threshold accounts for 768 kWh for electricity and 3048 kWh for gas[4].

Two tier tariffs have become more prevalent than standing charge tariffs – currently about 65% of tariffs on offer are two-tier[5 6].

Time of use tariffs which already exist in GB are :

- Economy 7. Supported by all major suppliers. 7 hours of lower rate electricity between 10pm and 8 am (actual times set by the DNO)
- Economy 10 (or Heatwise). Supported only by EDF, E.On and SSE. 7 hours of lower rate electricity between 7pm and 5 am, plus 3 hours between 12-4pm (actual times set by DNO).

Economy 7 and Economy 10 are mainly used by people with electric storage heating as high off-peak use is needed to benefit (the unit rate at other times is higher than on other tariffs). The tariff passes some of the benefit of lower over-night electricity system costs to the customer. Economy 7 and Economy 10 have been available in GB for very many years without smart meters, albeit many of the meters (not all) have a remote tele-switch capability. 31% of electricity consumed in 2008 in the household sector was reported as being purchased under some form of off-peak pricing structure[7].

1.3 Tariff-types to stimulate demand response – smart tariffs

In very broad terms, there are two main tariff-types to stimulate demand response – either to shift peaks or load, or, to reduce overall demand. Within these two main tariff-types there are many possibilities for tariff design, the main ones of which are summarised below. For more discussion on the various types of tariff see the references noted below.[8]

Tariffs to reduce peak demand and / or to switch load :

- **Time of use (ToU)** – two or more pre-defined periods with different prices at different times of the day to reflect peak and off-peak
- **Critical peak pricing (CPP)** – a substantially higher unit price for consumption for pre-notified short periods on a defined number of days when demand is 'critcially' high (e.g. one or two hours on the highest demand days). Many variations of CPP – CPP-reward or rebate (ie sharing of some of the avoided cost) variable-, fixed- etc.
- **Real time pricing** - dynamic rates that reflect short-term wholesale price changes in retail electricity prices (e.g. perhaps on an hourly or half-hourly basis)
- **Load control tariffs** - a lower unit price (or a bill rebate) in exchange for allowing control of the amount of electricity used for some appliances (e.g. heating, hot water, air-conditioning) from time to time.
- **Maximum demand** – a tariff which prevents a customer's peak electrical load exceeding a given threshold (eg common in France and Italy (non-smart)).
- **Interruptible gas tariffs for peak-management** – ie common in the I&C sector – but unlikely for households.

Tariffs to reduce overall demand :

- **Rising block** - a low initial rate per unit of consumption up to a specified volume, then higher unit prices in one or more blocks.
- **Overall Load Reduction Incentives / Rewards** (cash – or other incentives such as vouchers) – could be tied to energy saving measures

Are new tariffs and/or smart meters needed for household demand response?

This report considers the role of both smart-meter tariffs and other potential smart-meter related price incentives to stimulate household demand response. However, there are other ways of achieving household demand response that do not entail either a smart meter or a direct price-incentive to achieve response. For example appliances can be controlled automatically, either to switch-off at peak or high-cost times, or to provide continuous automated 'load-following'. However, it is likely that price-incentives would form part of such a load-control package, particularly in a market such as GB where customers can choose their supplier and there is no retail price control. Indeed, even in price regulated and non-competitive markets, price incentives have formed part of load management packages.

Direct Load Control (DLC) of this kind may offer households regular monthly bill credits in exchange for utility control of large electrical end uses, most commonly central air conditioning. One reason for the popularity of DLC programmes is that they have been feasible with the existing (non-smart) metering infrastructure.[9] Thus it might be more accurate to say that automated demand response does not necessarily require smart meters, but may require a price incentive to secure customer participation.

1.4 Consumer views on smart tariffs

There has to date not been a lot of research in the UK on consumer views of new forms of tariffs. However, Ofgem's Consumer First Panel (a group of 100 domestic energy consumers recruited to take part in a series of research events and surveys) has given views on different forms of tariffs.[10]

A small proportion of the Panel felt there should be no choice of tariff as it would make bills more complicated and make it even harder to compare different suppliers. The majority disagreed with this view, but new tariffs would mainly be judged beneficial if they helped save the consumer money and provided choice, rather than for their impact on energy use. Most agree that tariffs need to be simple (easy to understand), have a consistent format and structure (across suppliers) and be relevant to their usage patterns. It was suggested that tariffs should be structured to reward customers who are energy efficient. Many voiced concern that some types of tariffs could penalise some high users who cannot easily reduce consumption, such as those with a big family but a low income and those with medical conditions that require equipment. There is also concern about tariffs that penalise low users who may be single person households and elderly people. Most Panel members did not know if they are a high or low user, but assumed they are the latter, and so assessed tariff options on that basis.

'Time of use' tariffs received a mainly negative reaction. Many suggested they would need to make substantial behaviour changes, such as having appliances on a timer, or changing the time of day when they do their cooking or washing, to make cost savings. Most Panel members felt these changes are too much effort, making this tariff quite undesirable to the majority. There is a limited understanding of the purpose of such tariffs.

'Rising block' tariffs were viewed positively, seen as a good option for low users, and expected to increase efficiency. However, there are concerns about circumstantial high users - large families or with medical conditions. If such tariffs had three or more tiers, it would be complicated to understand which tier you are on at any given point in time. As with any tiered tariff, many felt suppliers should have to follow a set of guidelines that dictate where one tier ends and another starts, so that consumers could compare accurately across suppliers. Consumers would also need to have a very sound understanding of their energy usage to be able to decide if this tariff was suitable for them.

1.5 Smart tariffs that have been used outside Great Britain

Elsewhere, household demand response has been delivered over many years using a variety of incentives and pricing approaches, and, increasingly, through smart meters and tariffs. In the main, household DSR has been pursued where there are severe capacity or network constraints on the electricity system. Most smart tariffs have therefore been forms of time of use tariff (including critical peak pricing), to improve security of supply or to reduce the peak-related investment costs. So far, there has been little use of smart meter tariffs to deliver demand reduction overall, for example, through rising block tariffs or energy saving tariffs, and to date there have been no trials of smart tariffs for gas, although Ireland is considering one. There are many reports that provide considerable detail on the various tariff trials and experiments.[11]

Some of the key trials to date (all ToU and/or CPP) are as follows.

- **Ontario Energy Board Smart Price Pilot**. Run by the Ontario Energy Board (the regulator) from August, 2006 - February 2007,among 375 of Hydro Ottawa's residential electricity customers; plus a control group of 125 customers. Split between : TOU prices (3.5c/kwh; 7.5c/kwh; 10.5c/kwh); adjusted TOU prices with a critical peak price (CPP – 30c/kwh, but off peak rate reduced to 3.1c/kwh); TOU prices with a critical peak rebate (CPR) - a refund of 30¢ for every kWh reduction below their "baseline" usage during the critical peak hours. The load shifting during critical peak hours across all four summertime critical peak days ranged from 6% for TOU-only participants to 25% CPP participants. There was a 6.0% average conservation effect across all customers. 6.0%, 4.7%, and 7.4% for TOU, CPP, and CPR customers, respectively.

- **The California Statewide pricing pilot**, from July 2003 to December 2004 included 2,500 customers. Several different rate structures were tested: traditional time-of-use (TOU), where the peak price was 70 percent higher than the standard rate and about twice the off-peak price; two varieties of critical peak pricing (CPP) tariffs, where the peak price during a small number of critical days was five times higher than the standard rate. CPP rates produced reductions in peak demand ranging from 13-27%. TOU responses group by end of the second year. The greatest load shifting was observed amongst customers who also had enabling technology installed- electric heater controls, pool pump controls, or smart thermostats. The customers that received information/education were seen to alter energy consumption patterns initially, however there was no response in the second year of the trial. There was no change in total energy use - the reduction in energy use during high price periods was almost exactly offset by increases in energy use during off-peak periods.

- **The Northern Ireland Electricity (NIE) Keypad 'Powershift' trial** was undertaken with 200 Keypad (prepayment meter) customers from October 2003 to September 2004.[12] 100 customers ("Price Message Group") were given ToU tariffs(

4 time bands. 3 rates). They were compared to a control group of 100 customers who had a flat rate tariff. The ToU rates were 5.76p/kwh low; 8.64p/kwh medium; 15.36p/kwh high (9.146p / kWh was the comparable flat rate price for Keypad customers).The TOU tariffs achieved some load-shifting, but no overall electricity demand reduction. Powershift consumers saved money but not energy.

- **The Energy Australia Strategic Pricing Study** took place in 2006-07 and included 750 residential customers The experimental groups comprised: a control group; group provided only with information about peak load reductions; group placed on a seasonal TOU tariff; group placed on a medium critical peak pricing tariff with an inhouse display; and – two groups placed on a high critical peak pricing tariff with and without an in-house display. Critical peak prices were particularly high - $1 or $2/kwh. In summer, CPP tariffs achieved reductions in consumption during critical peak periods of between 5.5% and 7.8% -much of this saving came from reduced use of air conditioning. There was not a great deal of shifting of consumption from the critical peak period to shoulder, off-peak or non peak periods, so the majority of the reductions in CPP periods seen, resulted in electricity conservation.

Tariffs to reduce demand have not been used extensively anywhere. However, there has been some use of rising block principles for energy tariffs in some countries largely for social justice purposes. For example, in the Flanders region in Belgium, every household annually receives a free amount of electricity - 100 kWh per household, plus a further 100 kWh per family member. Senior citizens and disabled people receive the first 500 kWh free, under the social tariff provision. The costs of these free allocations are recovered in higher unit rates for all consumption above the free allocation. [13] It is worth noting that retail competition for household customers is only just beginning in Belgium, so these tariffs have operated in a price regulated monopoly market.

1.6 Smart Tariff Design for Great Britain - Principles

In considering design of new retail tariffs for GB smart meters there are some important issues of principle to consider.

- **Price Elasticity** – i.e. how much response to price signals is likely from GB household customers ? There is relatively little GB empirical evidence to inform tariff design (this question is considered in Chapter 6).
- **Cost reflectivity** - i.e. how far will tariffs designed to reduce or shift peak or switch load, and/or reduce overall demand reflect under-lying costs (fixed and variable) in the electricity and gas supply chains (ie reflect the actual costs of generation, production, storage, system operation, transmission, distribution, retail). How far will tariffs which are more cost-reflective serve either to deter or to attract or retain certain customer groups ? Interactions with licence conditions on cost reflectivity are also relevant here. (this question is considered in Chapter 4).
- **Fairness** - winners / losers and the proportion of customers who will achieve savings on their energy bills. Individual household consumption – together with the

flexibility / inflexibility of that consumption - are the key factors which will determine who gains and who loses in moving away from average-cost / flat tariffs. The basis by which the size and steps of any increments for block tariffs are determined – or the differentials by which peak and off-peak charges are shaped – are key considerations. This will partly be driven by likely elasticity – and also by existing customer consumption profile and current cross-subsidies among customers. (this question is considered in Chapter 2)

- **Distributional** – impacts of different forms of tariffs on low income and fuel-poor customers. This is a major issue. (this question is considered in Chapter 2).
- **Unintended outcomes** - eg certain tariffs may prompt substitution or fuel-switching (eg from gas to electricity). Such outcomes may be economically sub-optimal – unless all other tariffs are broadly cost-reflective. (this question is considered in Chapter 4)
- **Consumer understanding / acceptance –** avoiding the potential for higher-bills, confusion and possible negative impact on competition if consumers find new tariffs too complicated (this question is considered in Chapter 2)

Where retail markets are price-regulated, one start-point for development of new rising block or time-varying tariffs has been a goal of revenue-neutrality. However, in devising new tariffs in a non-price regulated market like GB, price-competition may be expected to act as a downward pressure and cost neutrality is not likely to be an explicit goal.

Lastly, in considering high-level issues for tariff design, different price interventions will stimulate different outcomes. Some clarity will therefore be helpful on whether the chief aim is to prompt one or more of the following :

- Peak shifting and / or load-following – ie to improve overall system economics (& system security)
- Overall demand reduction – to deliver overall economic and system savings – (eg by reducing the overall cost of delivering Obligations such as the RO, EU ETS).
- Carbon reduction
- Customer benefits – e.g. cash savings & affordability and new products and services offered by suppliers and / or others.

2. Potential impacts of smart retail tariffs on consumers

This chapter considers the impacts that various forms of smart tariffs for gas and electricity, that might be offered in the GB market, could have on consumers. Chapter 4 (in Part II of this report) examines the potential for household demand response (shifting times of use or reducing demand overall) to reduce costs in the electricity and gas supply chains. This will be key in determining whether new forms of tariffs and price packages will be cost reflective and thus whether they are likely to be economically attractive for suppliers to offer to customers. This chapter draws on these findings and also those on the implications for different market actors that are dealt with in Chapter 4).

This chapter starts by examining the two main tariff types in general terms and then looks separately at electricity and gas. It then considers what tariffs might actually be offered in the GB market and finally considers some important consumer issues raised by smart tariffs.

2.1 Consumers and peak demand / load shift tariffs (including time of use)

2.1.1 Overseas experience and consumer implications for Great Britain

Households do not have to be low users to benefit from peak demand reduction tariffs. By shifting consumption to lower cost periods (or having usage patterns that mean they use more in off-peak periods anyway) consumers could save money even if they do not use less energy overall.

In the California trials of Critical Peak Pricing, high-use customers responded significantly more in kW reduction than did low-use customers, but low-use customers saved significantly more in percentage reduction of their annual electricity bills than did high-use customers. Low-use customers saved an average of 4.0% on their electricity bills, while high-use customers saved an average of only 1.7%.[14]

In March 2007, Hydro One Networks Inc. ("Hydro One") received approval from the Ontario Energy Board ("OEB") for a pilot project involving 500 residential, farm and small business customers for 5 months (May to September 2007) to assess their response to time-of-use ("TOU") pricing.[15] Instead of paying the Regulated Price Plan ("RPP"), pilot participants were asked to pay the OEB-approved RPP TOU rates. In this pilot the peak period was 11am-5pm on weekdays, with 7-11 am and 5-10pm mid-peak and 10pm-7am off-peak. All times at weekends were also off-peak.

Most Hydro One pilot participants (76%) were better off with the RPP TOU rates during the pilot period. Customers who were better off on average gained about $6 per month, while customers who were worse off on average lost about $2 per month. 32% of pilot participants were better off on the RPP TOU rates without needing to use any less electricity overall. These customers are likely to have a greater percentage of usage during the mid-peak and off-peak periods. In the pilot, about 14% of customers were worse off under the

RPP TOU rates, despite making an effort to reduce their electricity consumption relative to the previous year. These customers are likely to have a greater percentage of consumption during on-peak and mid-peak periods. The researchers concluded that customers who are at home during the day will likely be negatively affected by the RPP TOU rates and will need to shift and/or conserve more in order to offset the impact. They also concluded that customers with low electricity usage are likely to be negatively impacted, as there is only a limited amount of load above the base load that they are able to shift or conserve.

Other recent international studies from the US and Australia also consider impacts of time-of-use / peak-pricing on different customer groups (eg large-users, low-income), and these also find that a large proportion of customers are able to obtain energy bill savings from peak-tariffs[16].

From a GB consumer perspective, some key implications of time of use tariffs need to be considered as follows.

- Substantial peak to off-peak differentials may be required to get a response. In the international examples peak to off-peak ratios of 5 : 1 or more have been seen with Critical Peak sometimes 10 times the off-peak rate (albeit not near being fully cost-reflective).
- Technology over and above a smart meter may be needed to obtain some demand response for some purposes in the supply chain. For example, some load-management or responsive services (eg for the system operator) may need high-speed capability in the meter, and/or a home energy management system or appliances may need electronic controls. These factors therefore impact on what pricing packages are offered to which consumers.
- Peak tariffs may need to be combined with automation and/or formalised in customer agreements to ensure 'firmness' in delivery of household demand-response. This is because suppliers will have to be sure of a response to enable them to reduce wholesale, network or balancing costs (see Chapter 4 for details). This has implications for consumers who may have to be willing to accept automatic control or contractual obligations to get the best tariffs. Automation may be better from a customer perspective as this removes the risks that might be present in contractual obligations.
- ToU/CPP tariffs in GB would mainly be for electricity. Design of the tariffs is clearly key in terms of which consumers win and which lose – i.e. what are the peak, medium and off-peak periods. The periods will be determined by electricity system costs and clearly can vary from country to country. In GB, peak periods of electricity demand are in the winter months on weekdays morning (7-9 am) and early evening (4-7pm) – particularly the latter as this is when household demand rises as people get home but business-use also remains high. Overnight (10pm-7 am) will be off-peak, whilst other times of the day are likely to be classed as mid-period. Weekends are likely to be all off-peak and mid-period.

- The potential for supply chain cost reductions might lead more to seasonal tariffs for gas rather than ones that vary by time of day. For consumers this could mean higher prices for gas in winter than in summer, with clearly important implications for the 80% plus of consumers who use gas for heating.

- DECC have raised an issue about the long term financial benefits to households of ToU tariffs. If large numbers of households, as a result of ToU tariffs, shift demand to off-peak periods, this increased off-peak demand could in time result in an increase in off-peak electricity prices and a lessening of the difference between peak and off-peak electricity prices. This may mean that the financial benefits to households of shifting their demand to off-peak periods reduce over time.[17]

2.1.2 Low income and vulnerable households and time of use tariffs

Whether low income and vulnerable consumers benefit from time of use tariffs will depend upon their usage patterns, whether they can respond flexibly and whether they can make sense of the information to adjust demand. There is mixed evidence from trials of time of use tariffs in other countries.

Results from the Northern Ireland time of use tariff trials suggested that many prepayment users there actually benefited from time of use tariffs without having to change their behaviour. The Keypad Powershift trial was undertaken with 200 customers from October 2003 to September 2004.[18] 100 customers ("Price Message Group" PMG) were given the Keypad time of day (ToU) time bands and tariffs(4 time bands, 3 rates). They were compared to a control group of 100 customers who had a flat-rate tariff (as per normal keypad customers). In the case of the control group the ToU bands were used to enable comparison of consumption within the same time bands as the price message group (i.e. did the price message encourage switching or do keypad customers have a different consumption profile from the majority of customers).

The average annual PMG spend was £371.98 compared to 393.54 by the control group on the standard keypad tariff. But if the control group had had the time-of-day price bands applied to their usage pattern, they would have paid £377.60. This may suggest that that much of the saving for the PMG was passive (i.e. reflecting lower use at peak periods by keypad customers in general) rather than an active response to the price signal. This may be because they are at home during the day and thus use appliances more at off-peak times.

Analysis from the California trials of Critical Peak Pricing showed that savings across income levels were statistically indistinguishable and that on average low-income households did not pay more under CPP tariffs. However, the lowest income households with high usage made no savings – as a result it was recommended that more should be done to help these households with efficiency measures particular if the tariffs are to be rolled out on a mandatory basis.[19]

Although the Hydro One TOU pilot study in Ontario did not specifically address the impact of TOU on Low Income Consumers (LIC), Hydro One have extrapolated from the report's findings to make some observations of the potential impact on low income customers. "LIC typically are characterized by: little or no ability to shift consumption patterns due to basic needs; high use of electric energy for space heating requirements, and poor house insulation and inefficient electrical appliances. TOU pricing of electricity will tend to penalize LIC since these consumers are not able to shift sufficient consumption away from peak periods to reduce peak charges and benefit from lower off-peak charges. Furthermore, LIC have little or no ability to improve on energy efficiency by investing in better insulation and energy efficient appliances as they have limited cash resources."[20]

The international evidence thus suggests for GB that many low income and vulnerable households could benefit from time-of-use tariffs for electricity, but low income households with on-peak electric heating (i.e. electric fires and some older types of underfloor heating, but not storage, as this is off-peak) may be the main group who could be disadvantaged. 9% (1.9 million) of all households in England have electric heating. Most of these (7%, or 1.5 million) have storage heating, with 1% (200,000) having electric central heating (e.g. underfloor) and 1% (200,000) relying on electric heaters. (EHCS, 2006) A breakdown of these numbers by income or social class is not available but, in 2001 it was estimated that 450,000 vulnerable fuel poor households did not have gas and it is likely that many of them were relying to a large extent on electric heating – although mostly this would be storage heaters. (FPAG 2003 paper).

The numbers of low income households with on-peak electric heating have probably reduced in recent years due to Warm Front and the decent homes standards in social housing. However, if electric heat pumps become more widespread in the future (and if they do not have a storage capacity and hence need to operate on-peak) then the numbers affected could increase. The lack of more up to date data and possible future trends towards greater use of electric heating, suggests this is an area that would warrant further investigation before more extensive use is made of time of use tariffs.

2.2 Consumers and overall demand reduction tariffs (including rising block tariffs)

Overall demand reduction tariffs would benefit households who are low users or who can reduce their demand. For example, such tariffs could incentivise households to fit better thermal insulation, replacement of inefficient boilers, improved thermostats and boiler controls. Consumers who cannot or do not respond in these ways could however, end up paying more.

Some key implications of demand reduction tariffs however need to be considered.

- Design is clearly important - increments and shapes of blocks, for example, how much gas or electricity is delivered at a relatively low price ; treatment of existing off-peak electricity (Economy 7 / 10) customers. Another issue is determining when customers move from one block to the next one – e. g. daily, weekly, monthly etc.
- Demand reduction tariffs could in time be unsustainable for suppliers who would need to recover fixed costs over fewer energy units. This may mean they need to increase the prices of the first blocks or apply a standing charge. Similarly cash rewards for consumers who reduce their consumption may be unsustainable if large numbers of consumers signed up to such pricing plans – suppliers might therefore prefer to offer non-cash rewards.

Rising block tariffs would almost certainly have to be introduced on a mandatory universal basis as otherwise only those who would save money would opt for them and large users would almost certainly switch, which would mean that these tariffs would quickly become uneconomic for suppliers. In practice, this would only be effective with some form of price control. The benefits that might accrue from rising block tariffs would probably not be sufficient on their own to justify such re-regulation of household retail prices. However, as noted below (para 2.4.5), development of voluntary monthly Pricing Plans may effectively share some features of a rising block tariff to incentivise energy demand reduction.

.

Low income and vulnerable households and rising block tariffs

Many low income households are low users and so could benefit from rising block tariffs, but there would be a problem for high-consuming low-income households (e.g. large families and those in properties which are expensive to heat). However, there may be ways to compensate these households (cash and/or energy efficiency measures) if they are few in number.

The Climate Change Committee has commissioned research on the impact of rising block tariffs on fuel poor households. [21] Four rising block tariffs were modelled to test out the impacts. Three were targeted at different groups of the fuel poor (e.g. only those without electric heating, only those over 60) some applied to electricity only, some to gas and electricity.

All the RBTs modelled resulted in a reduction in the numbers of households who are fuel poor and were particularly successful at removing elderly people from fuel poverty. But couples with dependent children were more likely to be fuel poor under each of the RBTs. Furthermore , although they reduced the numbers of households in fuel poverty, two of the RBTs actually increased the mean fuel bill of the fuel poor. This latter problem occurred because although more fuel poor households moved out of fuel poverty, than non-fuel poor households moved into fuel poverty, this was achieved at the expense of higher average bills for the group as a whole – hence there was no overall welfare gain.

The CCC report considers that the only rising block tariffs that could benefit the fuel poor would be those applied to electricity consumption in households without electric heating systems. RBTs applied to gas consumption would be likely to have a negative effect on the fuel poor. The researchers concluded that for RBTs to reduce fuel poverty they would need to be carefully targeted at specific groups and that this might be difficult for suppliers to achieve, therefore "as a method of mitigating against the rise in fuel poverty RBTs would appear to have limited potential. "

2.3 Rising block tariffs for environmental costs only

As an alternative to rising block tariffs for the whole bill, one option for serious consideration might be to apply a rising block principle just to the environmental costs within the bill – i.e. Renewables Obligation, EU ETS, CERT, and future schemes such as Renewable Heat Incentive, Feed in Tariffs and the proposed levy for Carbon Capture and Storage. This could make these charges more transparent and related to use – so high users would pay more.

Although there would be a rationale for doing so, applying the rising block principle to environmental charges would not be a straightforward option, because of the way some of the charges are structured. The easiest way to apply such a principle would be as a levy or a tax like VAT – i.e. a percentage charge added to the bill – this would therefore cost high-users more than low-users. However, the appropriate level would not be easy to calculate as some of the existing schemes are not currently set in cash terms – they are obligations that energy suppliers have an incentive to meet as cost effectively as possible. Thus to apportion the costs to customers according to a rising block principle would require a change to the nature of the charges and how they are applied. Other issues would also arise such as how to allocate the funds raised (would the funds be handed to an agency or would suppliers spend them directly, which might necessitate arrangements for transfers between suppliers).

The forthcoming Carbon Capture and Storage levy and the Renewable Heat Incentive levy will lend themselves most easily to being applied in this way. For these schemes the Government will set a levy-amount and specify how it is to be charged. Furthermore, it would be possible, for example, to exempt the first x units of consumption from the charge altogether to safeguard low-income low users and to reinforce the impact on higher users.

There would also be a number of important fairness and distributional issues to consider if the rising block principle were to be applied to environmental costs – for example, it would not be socially equitable whilst so many low income households live in properties that are difficult or expensive to heat. Applying this principle only to the environmental costs might also have a limited impact on usage (at least in the near term). However, given that 14-25 % percent of the bill may be attributable to environmental costs by 2020[22] this is an idea that warrants further investigation for the medium to longer term.

2.4 What might Great Britain smart retail tariffs look like ?

As outlined earlier, there are two basic types of retail tariff that may be offered with smart meters – time of use tariffs (to shift peak demand or load), and forms of tariff designed to reduce overall demand. This section now examines the application of each of these tariff-types to electricity and gas - and then goes on to consider some of the other variations that we may see in the GB market.

2.4.1 Electricity peak / load shifting tariffs

Electricity peak reduction tariffs (e.g. time of use tariffs) that incentivise lower electricity use at peak or at other high-cost times would reduce generation, network and system operation costs.

Suppliers could pass through some of their savings of avoided generation, network and system operation costs, in peak-reduction tariffs, to those customers who help reduce these costs on their behalf. Those who use electricity mostly off-peak or who can shift more of their usage to off-peak periods would gain from time of use tariffs – those who use more electricity at peaks or high-cost periods would lose. Experience elsewhere (Northern Ireland, Australia, and US) suggests that a large proportion of customers are able to obtain energy bill savings from peak tariffs[23].

As of today, the main appliances where households could benefit from off-peak tariffs are wet appliances such as washing machines, dishwashers and tumble driers. Households can vary the times at which they use these and they are large enough electrical loads to make it worth changing behaviour. Available bill savings may be modest now – but potential cost-savings from peak are likely to increase in the 2020s. The DECC Impact Assessment of Smart Metering assumes a 20% take-up of ToU tariffs, leading to a 3 % overall electricity bill reduction and a 5 % peak-use reduction.[24]

2.4.2 Electricity overall demand reduction tariffs

An electricity tariff which incentivised less electricity use overall (e.g. increasing block tariff) would reduce some generation, network, system and environmental costs.

Suppliers could pass through some of their savings on generation, environmental and system operation costs to those customers who help to reduce these costs. Pre-2020, scope for cost reductions (and hence benefits that could pass through to customers) would seem greater for overall electricity demand reduction than for electricity peak demand reduction – but this could reverse in the 2020s when both peak and some other system operating costs are expected to be considerably higher than now. Customers would see savings on their electricity bills if they reduce their electricity-use over a fixed time-period (say, annual)[25]. However, it is important to note that, if there was no time-of-use price message this would give no incentive to avoid peak time usage. Therefore, customers could use less electricity overall but not reduce (or could even add) to higher costs, for generation, networks and system operation. This might mean therefore, that to reduce overall system costs electricity tariff offers would need to be designed to incentivise both overall *and* peak demand reductions.

2.4.3 Gas peak demand reduction tariffs

Tariffs that incentivised reductions in peak demand for gas could theoretically reduce gas purchasing, storage and system balancing costs. 'Within-day' time-varying tariffs (eg peak and off-peak tariffs within the same day) would not however reflect current commercial arrangements in the gas market for a daily balance. In addition, there are very limited cost savings available to gas networks from peak demand reduction – gas networks are already sized to meet peaks - and household gas demand is not expected to grow significantly (and indeed may decline).

Suppliers could see some limited cost reductions that they could pass through to customers in peak-shifting gas tariffs Within-day household peak-pricing seems unlikely for the foreseeable future but off-peak rates for weekends or middle of the day or seasonal variations might have some commercial logic. This could reduce bills for some customers– but households with inflexible or large peak-time gas-use could suffer and/or the tariffs could trigger switching to electric heaters / water heating. Peak gas tariffs may in practice reduce demand overall, because some gas used for heating may not shift to another time of day – so customers could see bill savings from this effect.

2.4.4 Gas overall demand reduction tariffs

Tariffs that incentivised reduced overall gas use could reduce gas purchase, storage or balancing-related costs. Network cost savings are unlikely (as for peak demand tariffs).

Suppliers could see cost reductions that they could pass through to customers. Customers who respond to incentives to reduce gas use demand (e.g. through behavioural change, such as turning down thermostats, or having their heating on for shorter periods; through measures such as better controls, new boiler, insulation etc) should therefore see lower bills. However, over time, a block gas-tariff could perhaps serve to increase the peakiness of household gas-use (and associated costs) as measures to reduce unnecessary boiler-use (eg better adjusted boiler clocks, thermostats, insulation) begin to take effect.[26]

2.4.5 Lifestyle tariffs, pricing plans and other potential new offers

The actual range of tariffs offered by suppliers to customers could be much wider than the two basic types applied to single fuels. Actual tariff offers may be single or dual fuel and/or combine elements of time-of-use and overall demand reduction charging. Whilst there are important differences in the markets, it is possible that some of the sorts of offers seen in the telecommunications sector could spread to energy. These might include:

- **Lifestyle tariffs** – e.g. types of time-of-use tariffs designed to suit those who are at home all day; or out for most of the day; offering lower prices at evenings and weekends ; or for low-usage. Tariffs designed for different lifestyles are common in the telecommunications sector (e.g. different tariffs aimed at people who make mostly daytime or mostly evening calls). EDF already offers the non-smart Eco 20:20 tariff, for example. Eco 20:20 provides lower rate electricity between 9 pm and 7 am Monday-Friday (10 pm –8am BST) and all weekend.

- **Pricing plans** – e.g. the bundled minutes and texts commonly offered in mobile phone contracts. Energy pricing plans could offer a fixed price for consumption up to x kWh per month (which might mean a relatively low unit charge), but a relatively high unit charge for consumption above that limit. These plans could be sold alongside energy saving measures to help customers keep their consumption within the bundled amount. Such plans could be available in different forms for different types of customer (including for prepayment customers). In effect these could be a form of voluntary rising block tariff that could be compatible with a competitive market.

- **Energy or carbon saving tariffs**. Packages could include energy saving measures and financial or other incentives for reduced consumption. SSE's non-smart Better Plan is an example. Those who reduce their energy use by 10% in one year earn a £15 credit on their bills; those who reduce by 20% earn £25. There are further bill credits (£20) for customers who take up energy saving measures and customers who sign up get a free home energy display. The attraction for customers is the *total* saving – plus the 'reward'. These tariffs might develop in particular if new forms of supplier energy saving obligations post 2012 seek to encourage demand reduction or carbon saving. However, if suppliers were using such mechanisms to deliver an obligation they would need to be certain they could secure the demand reduction and also that customer interest would be sustained – this might require some automation, or contractual obligation or very strong price incentive to deter high usage.

- **DSM (demand side management) offers.** Customers willing to let their supplier automatically control certain appliances could be offered a price incentive for doing so. This could be useful particularly as a means to reduce demand briefly at peak or other high-priced periods – in this case customers should not notice any or much impact as the appliance would be off for short periods only. These offers may develop particularly in the future for those with electric storage or water heating, for refrigeration, or for electric cars. Direct load-control (DLC) programmes have existed in California and Florida since the early 1980s. These offer households regular monthly bill credits in exchange for utility control of large electrical end-uses, most commonly central air conditioning or water heating. One reason for the popularity of DLC programmes is that switching of appliances has been feasible with the existing (non-smart) metering infrastructure.[27]

- **Real-time pricing** (RTP) - One type of tariff option that may conceivably develop long-term - but is less likely in the near-term in the household sector in GB - is real-time pricing for electricity that closely tracks time-varying marginal wholesale costs. Half-hourly and hourly RTP tariffs have long been available to very large industrial firms in some countries, including in GB, albeit with limited take-up. RTP is generally considered too complex for small electricity users, and policymakers are reluctant to allow residential customers to face the inherently volatile wholesale market.[28] However, two examples of household RTP are : in Illinois, where state legislation has recently prompted the first RTP option for residential customers; and the Pepco PowerCents pilot in Washington DC, which (inter al) trialled hourly pricing with smart thermostats[29]. In the future, with significant wind and nuclear electricity in GB, there could be greater value than now in households providing flexibility through automated switching of certain load (e.g. refrigeration, hot-water, electric-car charging, price-responsive heat) and through micro-generation import and export. What might be most likely however, rather than full real time pricing for households, might be a simpler retail tariff with a load management payment or discount to households willing to sign up to provide such automated flexibility.

Passive monitoring of customer-usage patterns (initially without offering tariffs) and trials of different forms of tariff are likely to be very valuable in the short term as it will take time for suppliers to identify which tariffs (including the EDRP trials) will be attractive to customers and also which tariffs can deliver real value in terms of reducing costs, improvements in security of supply and environmental benefits.

2.5 Summary of potential impacts of smart household tariffs on different types of consumer

The two charts below serve to illustrate how different types of tariff would affect consumers with different consumption patterns – i.e. those with flexible and inflexible usage and those who use most electricity or gas at on-peak or at off-peak times. The impacts on low and high users are also considered in the charts.

Potential impact of smart household electricity tariffs on different types of consumer			
	Electricity Peak	**Electricity Load Control**	**Electricity Demand Reduction**
High Electricity Users			
Inflexible	**X**	**?** (eg fridge, water heater)	**X**
Flexible	√	√	**?**
On-Peak	**X X**	**?** (fridge, water heater)	**?**
Off-Peak	√√	√	**X**
Low Electricity Users			
Inflexible	**X**	**?**	**X**
Flexible	√√	√	**?**
On-Peak	**X**	**?** (fridge, water heater)	**X**
Off-Peak	√√	√√	**X?**

Potential impact of smart household gas tariffs on different types of consumer			
	Gas Peak	**Improved Control**	**Gas Demand Reduction**
High Gas Users			
Inflexible	**X**	**?**	**X X**
Flexible	√	√√	√**?**
On-Peak	**X**	√	**?**
Off-Peak	√√	√√	**X**
Low Gas Users			
Inflexible	**X**	**X?**	**X X**
Flexible	√	√	**X?**
On-Peak	**X**	**X?**	**X?**
Off-Peak	√	**?**	√**?**

2.6 Other important consumer impacts and interactions of new tariffs

As we have seen above, which customers gain and which lose will vary according to their consumption patterns and to the tariff types. However, because retail prices are unregulated, the impacts of new tariffs will vary according to how competitive the retail market is for different customer groups. Energy suppliers are likely to make attractive offers to customers they are keen to retain or attract – for example dual-fuel customers, and perhaps make less attractive offers to less commercially attractive customer groups.

Given that GB tariffs will be voluntary (opt-in) or offered only to certain customers (targeted), it is important to note that customers may face impacts whether or not they are on the new tariffs.

- Voluntary "opt-in" tariffs will encourage sign-up by participants who do not change their behaviour but who benefit because their pattern of use is best suited to the tariff type. Whilst this can be viewed as positive for those customers – they receive a "reward", such customers who sign up for a time-of-use tariff may do little or nothing to help reduce peak demand. (In economic parlance they would be described as "free riders"). If the rewards (e.g lower unit rates) exceed system benefits, other customers may have to pay higher electricity prices to pay for the bill savings enjoyed by the participants.

- Targeted tariffs may also result in non-participant customers paying more if the rewards to the participants exceed system benefits.

Conversely, where new tariffs do lead to overall cost reductions, non-participants may see some benefits, although these would be lower than the benefits to participants.

Two new licence conditions for domestic suppliers, introduced by Ofgem in September 2009 are intended to make the prices charged to customers more cost reflective. These conditions :

- Require any difference in the terms and conditions offered by suppliers in respect of different payment methods to be cost reflective; and
- Prohibit undue discrimination in any terms and conditions offered to consumers. This condition will cease to have effect on 31 July 2012.

These conditions were not drafted with smart tariffs in mind and one of them is also due to expire in 2012. New tariffs will be more complex and may therefore add a further dimension to understanding the relationship between wholesale and retail prices, how far tariffs are cost reflective and the extent to which and how suppliers share the benefits of cost reductions with customers. Consumer Focus has concerns that tariff complexity is already causing problems in the price comparison process.

Although Ofgem's quarterly market reports provide information on wholesale/retail price differentials more may need to be done to improve transparency in this area. Some form of licence condition on cost-reflectivity might therefore be useful as new smart tariffs are developed.

Other important considerations for consumers are :

- Payment methods may affect the impact of smart-tariff price signals. For example, households who pay by direct debit (c. 50% of households) have limited knowledge of their energy spend compared to those who use pre-pay, who are much more aware.
- The messages to customers from their energy billing, chosen payment methods, in-home display and any new tariffs linked to a smart meter need to be consistent and well-coordinated to enable consumers to respond in ways that will help them to reduce their bills and help deliver the public policy goals.
- How information on tariffs and other price signal is communicated to consumers will thus also be important. Displays and information on bills will be relevant here to ensure consumers know the prices at different times of day or when they are moving from low priced to higher priced units. Recent research by the Energy Saving Trust on displays shows how design of the consumer interface, its usability, and the extent to which it informs consumers or confuses them will be a key determinant of overall impact of smart meters and new tariffs and that greater emphasis on this is needed in product development and testing[30]. In some overseas trials (eg Ontario, Norway, Ireland), fridge magnets setting out the peak- / off-peak periods have proved a popular non-electronic prompt.
- Low income and vulnerable households will face many of the same impacts as other households from the introduction of smart tariffs. However there are also some more specific issues to consider. Some vulnerable households will find it difficult to respond to tariff signals by improving energy efficiency, due to lack of resources. Warm Front and CERT should help, but those in expensive to treat properties (off the gas network and/or in solid wall properties) could have particular problems. Some vulnerable households may cut back on heating too much in response to greater price signals – this may apply particularly to elderly people who already tend to underheat their homes.

3. Recommendations and Conclusions : Consumer Issues

3.1 Recommendations on consumer issues

Smart tariffs offer the potential for some significant consumer benefits but there are some important issues to address to ensure that consumers do realise the benefits. The following consumer recommendations are made.

- **Ofgem, DECC and consumer organisations need to continue to develop their understanding about potential winners and losers and the fairness and distributional issues arising from new tariffs and pricing plans for GB. Particular attention needs to be given to tariffs offered to low income and vulnerable households.** In particular, there is a need for better data on the extent of usage of electric on-peak heating amongst low income households (now and in the future).

- Savings on energy bills will drive customer interest in new tariffs. **In the current GB market, smart tariffs will be (and should be) optional for consumers. Consumers should not be locked into inappropriate tariffs that may be a bad deal for them.** Consumers will need to be fully aware of the potential implications of any new tariff structure on their bills, in the event of a change of circumstances e.g. loss of job, having a baby. **Ofgem and suppliers need to explore terms and potentially punitive arrangements to avoid 'lock-in' to unsuitable tariffs and ensure that consumers have enough information to make appropriate choices.**

- Although increased choice will be valuable, too much choice may actually be unhelpful. Ease of comparison will be key, so, **suppliers need to think carefully about the range of tariffs they offer to avoid complexity and confusion.** Lessons should be learnt from other countries and other markets. **Suppliers will need to work closely with consumer groups and the regulator to ensure clear, fair and transparent packages are on offer.**

- For consumers to be able to compare tariffs there will be a continuing important role for accredited price comparison web sites as well as clear information from suppliers to consumers. A code of conduct on suppliers, to govern how they operate within the price comparison market and how price information is presented would be helpful.

- Some new tariffs may be offered to customers as part of the roll- out of smart meters, although most new tariff offers may be made to consumers once their smart meters have been installed. As with other aspects of the roll-out there will be an important role for advice agencies, Ofgem and energy companies to ensure consumers are adequately informed. **In the smart meter implementation plan,**

Ofgem should review conditions governing energy companies' sales and marketing practices, especially on direct sales and tariff information to identify any needs for changes or strengthening. These issues should be considered by the Ofgem Smart Meters Consumer Advisory Group.

- It would be sensible for new tariffs to be offered to low income and vulnerable households where an independent advisor (e..g via Warm Front, Warm Zones) has helped to identify that it would suit the customer. **Suppliers should work in partnership with consumer groups to trial the impact of new tariffs and pricing structures on vulnerable and low income groups.**

- Ofgem, suppliers and consumer bodies need to identify how to ensure consistent messages to customers from energy billing, payment methods, in-home displays and any new tariffs linked to a smart meter.

- **Customers will need good feedback so that they can benefit from smart tariffs – e.g. to know when price periods or price blocks change.** Manufacturers, suppliers and consumer organisations need to consider how visual displays with smart meters could be programmed to help customers understand their tariffs using a variety of prompts (IHD, lights, alarms).

- Consumers may have concerns about usage and security of their data as smart meters are rolled out. New tariffs that seek to influence consumer behaviour might however, heighten concerns about privacy and data security issues. This is an area where suppliers need to work with consumer organisations, Ofgem and the Information Commissioner in the roll-out of smart meters to develop appropriate licence conditions, agreements and codes of practice on the ownership and usage of data. For example, consumers must have control over who has access to their own consumption data. Energy companies should not be able to share this data, which could be increasingly personal, with sales representatives without the consent of the householder. There will therefore need to be new rules governing this activity.

- **Consumers will need to be able to access their energy consumption data, including historic data to enable them to make comparisons between tariffs available and switch to the best deal for them. For comparison purposes there will therefore need to be agreement on common formats for energy consumption data – there will be a role for Ofgem here working with consumer groups and suppliers.** This consumption data should be available to consumers in a format of their choice – electronic, hard copy for example – and consumers should also have the choice of how they share this data with a third party – e.g. with a switching service or advice agency. Steps to ensure that customers can review and compare their energy consumption data, will need to tie back to current technical discussions on data formats for meter interoperability and functionality.

- The new licence condition that provides protection for consumers against undue discrimination was not drafted with smart tariffs in mind and it is also due to expire in 2012. **Ofgem needs to review whether a licence condition on cost reflectivity and/or transparency for new tariffs may be needed.**

3.2 Conclusions on consumer issues

There are potential benefits for consumers from new forms of peak-shift and demand reduction tariffs, but to ensure that consumers do benefit a number of important factors need to be addressed. There will be a need to avoid potentially punitive lock-in to unsuitable tariffs, and to encourage simplicity and transparency for consumers. There will also be a need to ensure that the benefits realised from smart meters and smart tariffs are reasonably shared between the companies and consumers (who after all are paying for the investment).

Although mandatory introduction of specific tariffs may be appropriate in price regulated markets and where customers cannot switch supplier, within the GB retail market, customers will expect to be able to retain choice over tariffs. This means that rising block tariffs, which would almost certainly have to be mandatory for all customers if they were to be effective, are not likely to be desirable in GB in the current market context. However, there are some forms of demand reduction tariffs that could be offered on an optional basis. And applying a rising block principle to the environmental costs is an idea that warrants further investigation.

Flexible and responsive customer load could in the future become a part of managing an efficient electricity system. Successful development of an active household electricity demand-side for Great Britain (to which new tariffs and price incentives could make a contribution) will depend upon willing customer participation. Key to securing this participation will be consumers seeing the benefits for them in terms of bill savings and making their contribution to environmental and security of supply goals.

PART II

SMART TARIFFS – DELIVERING PUBLIC POLICY, ECONOMIC AND COMMERCIAL BENEFITS

Part II of this report considers the following topics :

- Public policy potential of household demand response from smart tariffs - carbon, supply security and economic.
- Commercial incentives and regulatory issues for market actors in realising the potential benefits of household demand response from smart tariffs.
- Trends in GB household energy-use - pre- and post-2020 - and economic and carbon potential from household demand response.

4 Public policy potential of household demand response from smart tariffs

This section looks at how household demand response from smart tariffs could contribute to GB public policy goals for energy – carbon, security and cost-savings / affordability – and potential issues for different market actors in the electricity and gas supply chains in terms of realising the economic potential[31].

4.1 Carbon potential of household demand response

To get a household carbon saving we need to :

- Either reduce energy demand overall – either gas or electricity
- And / or reduce use of more carbon-intensive power plant.

For household demand response the picture for electricity and gas is different.

Electricity

Carbon-savings delivered from reduced household electricity-use (either from peak or load-shifting or from overall demand reduction) will not reduce emissions at the EU or global level given that power sector carbon emissions are already capped upstream under the EU ETS. Instead, the benefit will be a UK cost-saving from purchase of fewer EUAs (carbon emissions permits) to meet the UK's share of the cap. The assumption is that UK installations are unlikely to seek to outperform against their allocation [32].

Consumers may find it rather disappointing that efforts to reduce their electricity use will not count as 'additional' carbon savings for carbon-accounting purposes (although they would save money on their electricity bills). In future phases of the EU ETS it might be possible to take account of the potential for a greater household contribution in reducing electricity sector carbon emissions (through peak and demand reduction) - i.e. a tougher cap could be set on an assumption that greater household emissions reductions may be achieveable. Alternatively, the UK could continue to take the benefit of electricity demand reduction as cost savings in purchasing fewer EUAs.

However, it is also worth noting that carbon emissions from electricity should become less material from the mid-2020s assuming that the electricity system largely decarbonises.

Gas

By contrast, reduced household gas-use will deliver 'additional' carbon savings in terms of UK carbon accounting, because gas end-use is not capped in the EU ETS. Reducing household gas use and / or de-carbonising gas should therefore be a main focus for reducing household carbon.

The table below therefore summarises the likely impact on carbon emissions of different forms of demand response (electricity peak reduction, electricity overall demand reduction, gas peak reduction, gas overall demand reduction) pre and post 2020.

Table : Likely impact of household demand response on carbon emissions

DEMAND RESPONSE & CARBON SAVINGS	Electricity Peak-Response Note - Carbon-intensity of peak-generation expected to continue to exceed that of non-peak generation into 2020's and beyond.	Electricity Overall Demand Reduction	Gas Peak-Response	Gas Demand Reduction
Carbon Pre-2020	Unlikely to offer to 'additional' carbon savings for carbon accounting purposes due to upstream EU ETS cap. Savings now might help to make a case for a tougher cap in due course.	As electricity peak	Yes – gas-use suppressed at peaks would save carbon because that gas-use unlikely to be shifted to another time of day, (but may switch to electricity).	Yes – most effective for carbon due to lower gas use and/or switching from gas to electricity.
Carbon Post-2020	As above EU ETS cap may still mean that any savings not 'additional'. Any savings might help to make the case for a tougher cap ? Plus extent to which fossil plant still used at peak also a factor.	As electricity peak	Yes – as pre-2020	Yes – would save carbon as pre-2020 – but some substitution of bio-methane may mean less carbon emitted anyway.

4.2 Security of supply potential from household demand response

Household demand response (either peak/load-shift and overall) may deliver potential security of supply benefits for the electricity system or for gas supply.

If electricity demand becomes more responsive – or reduces at peak – this will help deliver security of supply – short run (improved system balancing / load-following / system security) and long run (avoided need for peaking capacity – generation, networks). If overall demand for electricity reduces – this will help deliver security of supply in electricity generation – but long-run rather than peak (ie avoided base-load generation, not improved peak / load-following).

For gas, reductions in both peak and overall demand could help gas security – reduced dependency on GB depleting fields, imported gas etc

Smart tariffs (by shifting either peak- or load, or reducing overall demand) could reduce the need for investment in new generation or network capacity for a given level of security of supply, or they could increase security of supply for a given level of investment. To avoid possible double-counting, therefore, we consider the security of supply benefits as potential reductions in costs – so see paras 4.3 – 4.4 below.

4.3 Economic potential in the gas and electricity supply chains from household demand response

This section considers in global terms where the economic potential from household demand response might sit within the gas and electricity supply chains. It draws from analysis in Tables in Annex 1, which look in turn at the four main tariff types and how these could perhaps impact on different market actors. Chapter 5 goes on to look at how this economic potential might be realised in practice, given how households use gas and electricity both now and in the future.

The table below provides a rough break-down of costs which feed into the end-price of household electricity and gas[33].

Rough Breakdown of Final Gas & Electricity Bill	**Electricity** avge annual bill – June 2009 prices – (qtly credit) £445 **% of End-Price**	**Gas** avge annual bill – June 2009 prices (qtrly credit) - £800 **% of End-Price**
Energy Costs	~56 without EU ETS	~60
Distribution	15	15
System Operator / Transmission	3	2
Supplier Costs	~13	~13
Meters	1	2
Environmental	8 (incl EU ETS, RO, CERT)	3 (CERT)
VAT	5	5

Based on the approximate proportions of costs in customer bills in the Table above :

4.3.1 Wholesale energy costs

Wholesale energy (fuel procurement and operating costs and capital costs of production, generation and storage) is the single greatest element of the household bill (50 - 60%) - so even proportionately modest fuel-cost savings from demand response are likely to be significant. Wholesale costs are also likely to remain a significant part of the customers' end-bill into the future. Potential wholesale cost savings could come either from short-run avoided fuel-purchase or other operational cost savings - or from long-run avoided or deferred investment in new electricity generation or gas production or storage.

Electricity - for electricity some peak benefits could accrue from household demand response pre-2020 although they would be more substantial post-2020 . The main long-run benefit will come from deferred or avoided investment in peak electricity generating plant and will be a particular benefit to integrated generators / suppliers (plus some limited fuel-saving). Non-vertically integrated generators may not benefit unless they are able to take advantage of demand response to achieve operational savings at peak (ie effectively demand-side hedge) or reduce imbalance exposure through load-following. Non vertically integrated generators may actually lose if peak-shifting or overall demand reduction leaves them with unsold output.

Gas - reducing overall gas-use could reduce gas purchase costs for suppliers and shippers. Household gas-use is highly temperature dependent and has strong peak characteristics (time-of-day, day-of-the-week, winter, seasonal shoulders), so reducing peak gas demand should enable lower gas purchasing costs and storage-related costs for suppliers and shippers (a main benefit). However, gas market commercial arrangements (especially *within*-day) would not directly incentivise within-day forms of peak-pricing (eg daily time-of-use) for household gas[34].

4.3.2 Network costs

Network costs (transmission and distribution) - form the next biggest portion of the household bill but are much lower than the wholesale energy cost (~20% - 15% Distribution ; <3%Transmission).

For electricity, in average terms, the potential for network savings through demand response is likely to be smaller than savings available for reduced wholesale costs (although significant location specific cost-savings could be available on individual parts of the network).[35] Distribution networks are built to cope with expected peak demand and generally, as of today, DNOs can adequately meet the peaks occurring on their networks. Peak-demand reduction could reduce losses[36], but beyond this may offer relatively modest economic or operational value to the networks as at today. Potential network peak-cost savings are most likely post-2020, with significantly more Renewables, and if and when responsive electricity demand grows significantly (electric vehicles, off-peak electric heat). The savings would be mainly deferred / avoided costs of network reinforcement / new investment. Post-2020, additional (and perhaps significant) savings are likely to be available from loss reduction. Networks could in time pass through reduced network charges to suppliers in return for suppliers (or others) being able to guarantee a given and sustained level of household peak reduction. A significant reduction in network costs is unlikely from reducing overall throughput of units (ie through overall demand reduction) because network costs are driven by peak requirements.

There are very limited cost savings available to gas networks from demand reduction – gas networks are already sized to meet peaks - and household gas demand is not expected to grow significantly (and indeed may decline).

4.3.3 System operator costs

System operator costs form a small proportion of the overall end-bill, but economic efficiency is nevertheless very important.

For electricity, there will be improvements in overall system efficiency costs if household demand-response can offer an additional / competing resource for load-following and for peak - over and above existing options open to the system operator. System balancing costs form a small proportion of the overall electricity end-price – but balancing costs are expected to increase significantly into the 2020's due to evolution of the generating mix (increased nuclear (inflexible) and wind (intermittent)). So, reducing peak-related or system balancing costs will become increasingly important in the 2020's and demand-side flexibility is likely to have a high premium. As for networks, there may be significant locational benefits. Lower imbalance costs could feed through into lower imbalance charges for integrated and non-integrated generators and suppliers.

Overall electricity demand reduction - does not necessarily reduce either peak or load-following costs for the SO. However, additional potential cost-savings in system balancing if less electricity demand overall enables SO to contract for less reserve plant.

For gas (unlike electricity, commercial arrangements for gas balancing are daily rather than within-day. However, there are still possibly some cost efficiencies in improvements in balancing the gas system at peak or shoulder periods – e.g. managing highly seasonal aspects of demand, pipeline pressure, storage. There are also potential cost-savings if, for example, lower overall gas-demand enabled some avoided investment in short-term operational storage.

4.3.4 Supplier costs

Demand response is unlikely to have a major impact on direct supplier costs (but note that £6.2 billion (pv) supplier cost-savings are estimated from reduced cost-to-serve from smart meters). The major cost impacts for suppliers from demand response will be on what they pay to other parts of the energy system supply chain – i.e. reduced wholesale energy purchase, better contract match, and reduced charges (potentially) for use of networks and system balancing – plus environmental charges.

4.3.5 Environmental charges

Environmental charges (e.g. the EU ETS, the Renewables Obligation, Feed-In Tariff, forthcoming Renewable Heat Incentive and CCS levy etc) are a growing proportion of the bill.[37]. Reduced electricity demand will potentially make it easier for suppliers to meet the renewable electricity target and thereby, for example, able to save on RO-related costs. Reduced demand overall could also benefit generators as they may need to purchase fewer EU ETS permits. By contrast, reduced electricity demand at peaks will only reduce environmental costs if the demand is not shifted to other times of the day.

Reduced gas use overall will contribute to carbon reduction and should make it easier to meet the renewable heat target which will reduce costs to gas suppliers (ie reduce RHI liability).

4.3.6 Conclusions on economic potential from household demand response

In terms of electricity and gas supply chain costs :

- Gas savings both pre- and post-2020 are likely to offer significant economic value – especially in the face of probable long-term rising real prices.

- In the 2020s there will be significant economic value in the electricity system from demand-side flexibility. However, unless significant new responsive electricity demand materialises (refrigeration, water-heating, electric vehicles, heat), flexibility will be provided only on the supply-side, including potentially from peaking generation plant and / or embedded generation or microgen – almost certainly at higher cost.

- Electricity savings - both pre-and post 2020 - will reduce costs to the customer and to the electricity system as a whole – by reducing wholesale electricity costs, supporting economic delivery of security of supply, and by enabling Obligations (EU ETS, RO) to be met more cheaply.

- Potential demand-side cost-savings to the networks are mostly electricity peak-related (ie not gas), and much may turn out to be very location-specific (e.g, at a particular electricity sub-station). Distribution networks would need to develop demand-side measures to reduce constraints or provide "bottleneck" management , together with suppliers and generators. Moreover, *every* supplier would need firm / bankable peak - or maximum demand - arrangements with each network (or section of network), to secure reductions in network charges.

- System Operation – demand-side flexible load-following or peak-response could offer a potentially competitive alternative for system balancing – either to flexible electricity back-up plant or to storage for gas. Reduced overall electricity demand could help to reduce reserve-related costs.

- Suppliers are likely to find it easier to realise potential available wholesale savings – ie short-run power-procurement or gas purchase or other operational savings - and long-run savings from deferred or avoided capacity investment (peaking plant, storage) – because these savings are more under direct supplier control - than possible savings from network charges.

- Integrated players could find it economically beneficial to reduce demand overall, both pre- and post-2020. In the 2020's, operational flexibility will command a premium, and so tariffs to reduce peaks (or, in a wind-dominated system, to load-follow) will become increasingly economic for suppliers to offer to their customers.

4.4 Economic incentives on suppliers to offer different types of tariff

The following three tables illustrate how some of the economic incentives described in this Chapter could prompt different market actors to promote different kinds of tariff to encourage a household demand response.

4.4.1
Incentives for demand response in the GB electricity supply chain - pre- & post-2020.

ELECTRICITY – Illustration of economic potential for market actors and consumers from electricity household demand reduction or peak avoidance / load following tariffs				
	Demand Reduction		**Peak Avoidance / Load Following**	
	2010*	2020's	2010*	2020's
Electricity Suppliers – integrated	√√	√√√ Reduces RO liability	√	√√√
Electricity Suppliers – non-integrated	√	√	√	√√ Hedge against price volatility
Electricity Generators – integrated	√√	√√√ Reduces EU ETS costs	√√	√√√
Electricity Generators – Non-integrated	x	x	x	√√ Hedge against price volatility / less predictability
DNOs / TO	x	x	√ Losses	√√√ Losses. Avoided investment (provided new flexible demand materialises) – benefit may be local
System operator	√	√√	√	√√√
Environmental costs - electricity – ie avoided costs of Obligations (EU ETS, RO)	√√	√√√	x	x
Customers - Electricity	√√	√√√	√ (available 'discretionary' or price-responsive load from households may be modest – say 20 to 25 % of all household appliance load).	√√√ (subject to more responsive household load (eg electric cars & price-responsive heat)

*Notes - Central estimates for central comms case - DECC GB Meter Impact Assessment. December 2009.
Smart Meter Electricity Demand Reduction - est. 2.8% * – ie say ~3.5TWh – (total household electricity demand in 2008 - 118 TWh). Valued – £2.5 bn pv. Assume £14 saving per customer pa per fuel from improved feedback from smart meters - **but does not necessarily incorporate additional demand reduction potential from new demand-reduction incentives or tariffs.**
Smart Meter Time of Use Tariffs – estimated 5%* peak reduction at an uptake of 1 in 5 customers for new off-peak demand (ie above & beyond existing off-peak) – valued £358m pv (and a 3% demand reduction for these customers)
Load Shifting - not specified – but valued at £617m pv
EU ETS avoided allowance purchase - £460 m pv. Traded sector carbon savings over 20 years – 15MtCO2
Reduced Losses - £390 m (split 50:50 customer and networks).

4.4.2

Incentives for demand response in the GB gas supply chain - pre- and post-2020.

GAS – Illustration of economic potential for market actors and consumers from gas household demand reduction or peak / load tariffs				
	Demand Reduction		**Peak Avoidance**	
	2010	**2020's**	**2010**	**2020's**
Gas Suppliers - integrated	√√√	√√√	√	√√
Gas Suppliers – non-integrated	√?	√	x	√
Shippers - Integrated	√√	√√√	X	√√?
Shippers – Non-Integrated	x	x	x	√√ ?
Gas Networks	x	x	x	x
System operator	√	√√	√√	√√√
Environmental costs Gas - ie avoided costs of Obligations (RHI ?)	√	√√ Reduced RHI costs ?	x	√ ?
Customers - Gas	√√	√√√	√	√√√
*Notes - Central estimates for central comms case - DECC GB Meter Impact Assessment. December 2009. **Smart Meter Gas Demand Reduction - est. 2 % – ie say 7.2 TWh – (total household gas demand in 2008 – 360 TWh). Valued – £1.9 bn pv.** Assume £14 saving per customer pa per fuel from improved feedback from smart meters - **but does not necessarily incorporate additional demand-reduction potential from new incentives or tariffs**. **Global CO2 reductions - £896m pv**. Non-traded sector carbon savings over 20 years – 24 MtCO2				

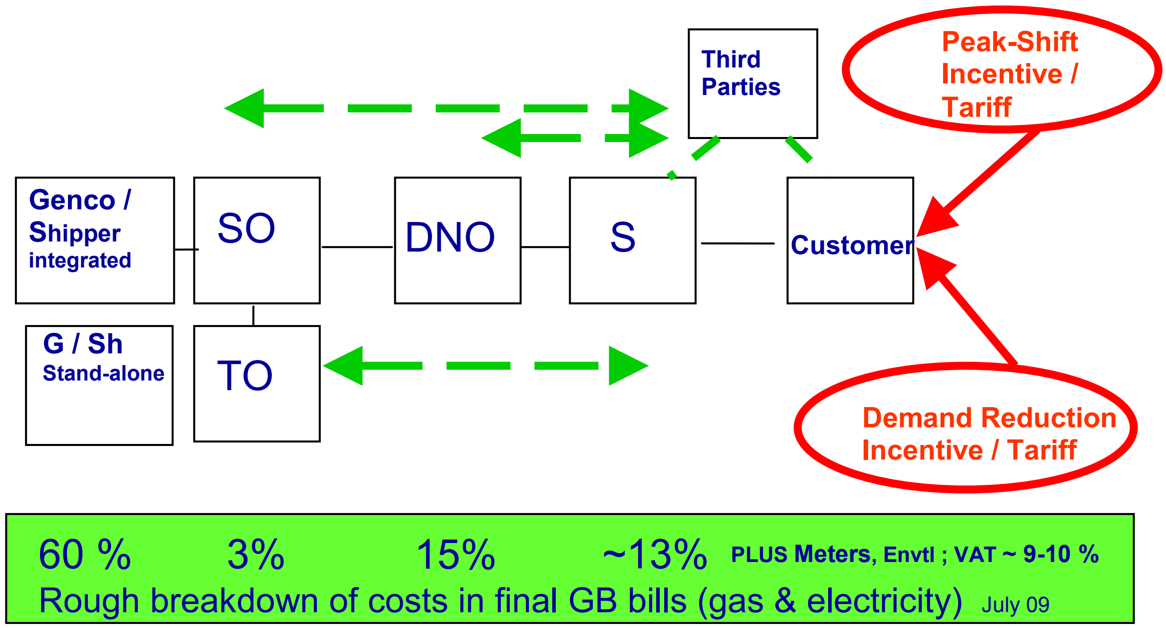
4.4.3

Electricity and Gas - some potential GB household smart tariff-types – reflecting commercial interests of market actors

Table : Electricity and Gas - some potential GB household smart tariff types – reflecting commercial interests of market actors

Electricity Peak / Load Following	**Gas Peak**
ToU – daily, weekend, CPP, CPP with automation **Peak, Load Following, Reserve Services to System Operator** eg Frequency Response, Reserve – fridges, water heaters, electric cars, responsive heat. **Peak Services to Networks** – Maximum Demand, Load Control	**Peak** – Less likely under present commercial arrangements - but could consider ToU – eg morning, evening & weekend rates. CPP, CPP with automation **Seasonal** – could take gas pricing higher in winter & spring & autumn – but what to do in summer ?
Electricity Demand Reduction	**Gas Demand Reduction**
Block – but issues about cost-reflectivity **Overall Load Reduction**	**Block** **Overall Load Reduction** **Boiler Related** – Improved Efficiency / Better Control – thermostat / boiler clock

5. Commercial incentives and regulatory issues - realising the potential benefits of household demand response.



Identifying the technical and / or economic potential for savings from smart tariffs as in Chapter 4 does not in itself ensure delivery. Commercial incentives and regulatory arrangements will affect different market actors and shape what is 'achievable' and it is therefore important to understand the key issues and barriers. These will vary :

- **For different market actors** - in particular given the interplay of the customer / supplier relationship - and relationships with other actors (networks, production, system operation) - and also with third parties engaged in delivering energy saving and / or micro-gen (Aggregators, ESCOs, local authorities et al).

- **In different time-scales** – operational (short-run) and investment (both today / 2020's).

- Depending how far cost-reflectivity / economic efficiency is a major regulatory driver – including for retail tariffs

- Depending on whether the drive for energy and carbon savings is mainly policy – or commercially-led.

It is also important to understand how the potential value of cost reductions may vary among different players. For example :

- **Where existing costs can be passed through in full to someone else -** where networks can pass through costs to suppliers (e.g. via use of system charges) and on to end-customers; generators/shippers can pass through power and gas purchase costs to suppliers and on to end-customers - then there may be little incentive to reduce those costs. This lack of incentive could apply particularly if reducing costs results in other costs (actual or opportunity costs – e.g.management time, diversion of effort from more profitable activities etc).

- **There are differences between integrated and non-integrated generators**. For generators or shippers who are vertically integrated with supply businesses, selling fewer units may not be unduly problematic if the revenue can be made up in other ways (e.g by increasing market share, or developing new energy services). However, stand-alone generators or shippers whose only source of revenue is to sell units of energy may have little interest in selling fewer units (unless as a short-run way to hedge risk).

- **If costs produce revenues in excess of those costs** (i.e. profit) - then there will be little incentive to reduce them – e.g. for networks this will be affected by regulatory treatment (e.g. a larger RAB (regulated asset base) produces a proportionately larger return) ; for suppliers this will depend upon the relationship between wholesale costs and retail prices.

GB market actors may find that they have little commercial or regulatory incentive to deliver certain cost-savings to the benefit of the overall energy system where the benefit may largely fall to other players – or, worse, impose a new cost on them in facilitating delivery to others.

Some considerations are therefore :

- **If suppliers sell fewer kWh (electricity or gas) via demand-reduction tariffs, then in time they will need to recover their fixed costs over fewer units.** This may encourage them to develop their businesses to make up lost revenue in other ways. For example, by increasing their customer base or developing new energy services. Alternatively, it may lead them to raise prices to some customers (see Chapter 2 for more on this).

- **Between market players, commercial agreements should capture required actions, benefits and rewards for household demand response – but *actual delivery* depends upon success of suppliers in incentivising households via retail tariffs / offers.**

- **Third Parties – Aggregators, ESCOs, and DNOs should bring new value, competition and innovation in household Demand Response, but also some complexity in terms of benefit share, supplier risk and multi-party agreements.**

- **Suppliers are well-placed to build upon on their existing direct relationships with customers in making tariff-related demand-side agreements.**

- **Agreements : Potential agreements or contracts may be needed** between :
  - customer – supplier
  - supplier – system operator
  - supplier – network
  - third-party (eg Aggregator, ESCO, DNO) with – customer ; supplier ; network or system operator.

  - **In particular, some kind of high-level agreement on information-sharing may eventually be needed between third-parties and suppliers** – or third-parties may need to become licensed suppliers themselves. Once household Demand Response develops on a meaningful scale, suppliers may find themselves less able than today to predict customer consumption and so they may become increasingly financially exposed to unpredictable or unknown demand-response arrangements put in place by third-parties (see Double Counting below).

- **Existing industry codes and agreements may already cover some aspects – but it is likely that existing agreements may either need adapting or new agreements needed.** (Potentially similar issues arise in respect of the demand-side characteristics of embedded generation or microgen (ie which when exporting can have an equivalent effect to a reduction in demand in terms of the overall balance of supply and demand).

- **The economic and practical difficulties caused by the need for many millions of new household-level agreements to deliver household demand response where each agreement has a small value**. Aggregation by suppliers themselves, or, or by third-parties will be necessary and this in turn raises the possibility of high transaction costs and some complexity. Third-parties may contract with others (including customers) to deliver demand-response and capture any associated cost-savings, but these may need to be fairly material, or, in high volumes, for there to be enough benefits to share. Furthermore, the benefit to each contracting party would need to be sufficient to make it worth-while for each to participate – ie to reduce demand, to invest in automated equipment etc. Possible examples are : the emergence of aggregators providing frequency responsive services eg from refrigeration (or, in the long-run, electric vehicle charging) ; energy service companies installing measures and at the same time incentivising reduced usage through demand-reduction tariffs.

- **Demand reductions (either peak or overall) will need to be firm (potentially guaranteed) before either network or procurement costs can be avoided** – ie both for short-run operational benefit and for potential long-run avoided investment to be realised. This will almost certainly require supplier control – such as automatic load control (or an enforceable contract e.g, with an aggregator/ESCO who takes responsibility for reducing peak or overall demand) . Household-level DSM agreements are common in the US. **For GB, questions arise as to the nature and duration of customer agreements likely to be needed for firm delivery and aggregation ; additional equipment over and above the smart meter may be required and suppliers and / or third-parties may look for long-term agreements to prevent stranding of any equipment or measures they install ; the acceptability to customers of automatic control ; and, the potential need for customer protections.**

- **Network charges** - Eventually, some actions for demand-side savings instigated by suppliers or others could potentially translate into savings in network charges – but would need regulatory recognition – and this could take time to agree and reflect in network charges to suppliers. ie there may be a time-lag until suppliers are able to obtain the benefits of any savings they create for DNOs. The recently concluded distribution price control review (DPCR5) has begun the process of neutralising incentives for networks as between new investment in peak-assets against taking more innovative demand-side actions. However, for network cost-savings from demand-response to translate quickly into reduced network charges for suppliers, it is probable that further evolution may be needed. Emerging thinking with respect to crediting 'negawatts' in distribution use of system charges for embedded generators may perhaps point the way. Such incentive arrangements are likely to be for consideration at a future Distribution Price Control Review.

- **More small customer profiles / Settlement (potentially) for individual household customers – there is likely to be a need to to develop many more small-user demand profiles.** Otherwise, suppliers may fail to capture the full economic value of any individual demand-side actions they may have put in place with their own customers. Under the present (very limited) profiled settlement arrangements for small users, the financial benefits from demand-side savings initiated by an *individual* supplier (and which ultimately could help deliver reduced production, improved contract match, or, avoided capacity or network investment) - will be socialised among *all* suppliers. Potentially, suppliers stand to lose twice-over : by failing to capture the full benefit of their own investment ; and, by creating reduced costs for their competitors. This is likely to prove a disincentive to supplier demand-side investment. As smart meters are progressively rolled-out, accurate settlement for small users will become feasible, albeit potentially involving additional costs in respect of data handling and even billing[38].

- **Double Counting of Benefits -** there will be a need for greater clarity on where the delivered economic benefits of either demand or peak-reduction fall – and how this is to be reflected in agreements – and clarity on what priority to be given to the differing needs of the supplier, network or system operator. This area is presently not well-understood in either commercial or regulatory terms[39].

Conclusions on commercial incentives and regulatory issues

There are many issues of principle and practicality to consider before market actors can realise the full economic potential of a household demand-side.

Integrated suppliers, generators and shippers may be best-placed to capture benefits both of demand- and peak reduction via a 'least-cost' approach through :

- Improved match – power-purchase, gas procurement, imbalance
- Avoided supply-side capital expenditure in long-run (peaking plant, gas storage)
- Reduced overall costs to suppliers of meeting Obligations (costs of RO, EU ETS).

Stand-alone players – could possibly benefit from peak-avoidance or improved load-following (eg by reducing imbalance risk through demand-side hedging) – but will perhaps find little benefit in demand reduction.

Network Savings are available to DNOs and TO (but not to gas networks). These cost-savings are mainly peak-related, and for now, seem generally modest because networks are already sized to peak. In the 2020's, the economic benefit of avoided network investment from demand response looks far more substantial (if high volumes of electric cars and electric heat) – albeit the benefits may turn out to be very location specific.

System Operator – may be able to reduce reserve or obtain some additional response services from a household the demand-side – but this seems more likely in the I&C market first.

The core commercial and regulatory question seems to revolve around whether incentives are there for the suppliers to reduce demand or peaks for other market actors. As noted, this seems to work in the case of the integrated players – or where a market in Services already exists (eg as for the system operator) – but for delivery of peak-avoidance by Suppliers to the Distribution Networks, more responsive incentives through revised network charges may be needed.

Settlement – changes are also likely to be needed to the deemed household profiles or to settlement arrangements to enable individual suppliers to capture the full value of their demand-side investment.

6. Trends in GB household gas and electricity use - pre- and post-2020 – and potential value of GB demand response

In seeking to understand more about how energy tariffs from smart meters and other price incentives may in time influence GB household energy use and carbon emissions, this Chapter considers :

- Some general points on price elasticity
- Trends in GB household energy use
- How household use of gas and electricity might respond to a price incentive or tariff – i.e. what load might shift or switch off – both pre- and post- 2020.
- Potential value of available economic and carbon savings from GB household demand response

6.1 Household energy price elasticity

Before examining the potential for demand responsiveness it is useful to note some brief background on household energy price elasticity. Price elasticity[40] shows itself as one or both of :

- An overall reduction in consumption when the price increases
- A shift of (electricity) usage from some hours of the day to others when price differentials change

There is a substantial international literature on electricity price elasticity and a recent EPRI paper synthesises findings from eighteen earlier pilot studies [41] . It concludes that : a wide variety of consumers exhibit electricity price response when provided with an opportunity ; that differences among individuals and groups are useful for singling out those most likely to benefit (and therefore for early participation) ; and that the relative tight bunching of elasticity estimates from a variety of electricity pilots involving different customer segments under different market circumstances suggests that price-response impacts can be estimated quite confidently and accurately.

Other findings highlighted by EPRI were : around three-quarters of the measured price-response is attributable to one-quarter of pilot participants ; it is not necessarily only large users that are price-responsive ; the character of the pricing plan (ToU, RTP, CPP) can make a difference in the level of price response ; electricity price-elasticities are not constant values – but are influenced by the timing (day, season, duration) and the level of the pricing change as well as the flexibility (or scope for substitution) available to the individual ; and, importantly, that automation can foster greater response than complex pricing plans.

There are also important differences between short-run and longer-term and sustained substitution / changes in energy-use in response to price.

Detailed technical understanding of likely price elasticities is important for actual tariff design – in particular, for peak-pricing tariffs in seeking to establish appropriate ratios / differentials between peak, off-peak and shoulder prices, or in establishing the shape and size of blocks or tiers for demand reduction tariffs. In international trials, ratios of 5:1 for peak / off-peak rates are common and as much as 10:1 for some CPP price differentials (albeit these differentials not fully cost-reflective).

Most available studies on price-elasticity reflect international experience, including the dominance elsewhere of electricity as a fuel for household air-conditioning and for space and water-heating. Overall, these studies consistently find that time-of-use rates can induce a drop in peak demand that ranges between three to six percent and that critical peak pricing tariffs induce a drop in peak demand that ranges between 13 to 20 percent. When accompanied by some element of automation, CPP tariffs lead to a drop in peak-demand in the 27 to 44 percent range[42].

For GB, there is relatively limited empirical evidence in respect of household energy price response. However, some interesting pointers may be :

- Overall, from 1970, fuel-price variations are not attributed to having had much direct effect on domestic energy use, except perhaps in the period post-2005. BRE, in taking a long view, suggest that physical and other factors rather than price seem to offer the best explanation of the observed pattern of domestic energy use in GB (albeit not true for households unable to afford their desired level of use)[43] .
- In the decade 1998 to 2008, real prices for energy rose 60% - with the real price of electricity increasing by 37% and the real price of gas increasing 78%[44] .
- From 2005 to 2007, changes in final household gas use (down 12%) and electricity use (down, but far more marginal) were attributed to these real-terms price increases.
- In 2008, total domestic energy prices increased in real terms by 16%. Electricity prices increased by 13%, gas prices by 17%[45]. Despite these real-terms price increases both household gas and electricity demand ***rose*** in 2008 and again in winter 2008/9 due to lower average temperatures than in 2005, 2006 and 2007[46].

Separately, GB experience with industrial and commercial customers may hold some clues as to the value they place on supply and the extent to which they may be price elastic[47].

For households, the GB Energy Demand Research Project which began in July 2007 is understood to involve some limited piloting of time-of-use electricity prices (but not gas) and exploration of incentives for demand reduction (both fuels). Hopefully the GB trials may shortly offer some initial insight into GB household energy usage and potential customer price-response for both gas and electricity. This will enable suppliers and consumer bodies to gain some important practical knowledge about the potential impacts of time-varying or volume-varying prices on GB households – including on those with different levels of consumption, different flexibility of consumption and across different income groups – and the enduring nature of any effects (or not) and for this understanding to feed into considerations around key principles for tariff design and customer safeguards.

6.2 Trends in Great Britain household energy use and carbon emissions

At 28% of UK final energy-use, the household sector comes second only to transport for end-use consumption. Just over one-third of all electricity produced and around one-third of final gas-consumption is used by households.

Of energy used in UK homes, just under 70% is gas and 22% electricity. End-use of energy in UK homes breaks down broadly as follows :

- Space and water heating around 80% - of which space heating around 60% and water heating around 25% ;
- Lighting and appliances ~ 15 % - still the fastest growing segment.
- Cooking - ~ 3%.

From 1990 to 2004 household energy consumption rose by 1.4% per annum - 19% in total - reflecting a steady long-term trend. Notably this rate of growth was only partly offset by an equivalent 19% improvement in energy efficiency over the same period (improved boiler efficiency, new-build regulations, and improved insulation).

Household energy consumption has risen - and may continue to rise - due to : more and smaller households, higher disposable income, householders habitually maintaining their homes at warmer average temperatures[48], and increased availability of lighting, appliances and electronic goods in homes. The trend both to more households (up 16% since 1990) and to smaller households contributes to increased energy consumption per head, despite downward total consumption per household[49].

Around 27 % of all UK carbon emissions are attributable to household energy consumption (or around 13 % if power station emissions are excluded on the basis that they are already capped upstream) [50]. Since 1990, household carbon emissions have increased by 2% - in a period when household energy consumption (excluding electricity) increased by 9.5%[51]. Effectively, household carbon emissions have been on an improving trend – but have not declined as quickly as energy demand for heating and hot water has grown. Around 60 % of carbon emissions from households are attributed to domestic boilers[52].

6.3 Great Britain household gas use and potential price response

Gas dominates both space and water heating - at around 80% for each. Around 20 million homes have gas-fired heating systems (~90% of domestic heating systems – less in Scotland)[53]. Despite higher average indoor temperatures, household gas demand is however judged to be largely saturated and possibly starting to decline. Largely, this is due to more efficient boilers, better controls and to continuing improvements in thermal insulation.

Average household gas use (on an equivalent kWh basis) is around five-times greater than electricity. On average, gas is the largest household fuel bill by around one-third despite being the lower cost fuel[54]. Gas-use is highly correlated to external temperature, with around five or six-times more gas being used in winter than in summer (summer-use: mostly cooking and water-heating).

Recent experience indicates that household gas customers responded to higher real gas prices (or anticipation of higher prices) by reducing their consumption. Household gas use fell by 12% overall from 2005 to 2007, adjusted for temperature, income and policy. Interestingly, in 2008 in response to lower average external temperatures over the year than in 2007, household gas use rose by 2.9%, despite domestic gas prices rising again in real-terms[55]. It seems possible to draw the following initial conclusions :

- Recent trends in household gas-use suggests that there appears to be some available price-response for household gas.
- The high correlation between external temperature and gas-use in home-heating suggests that any household gas price response plateaus when the weather is sufficiently cold – ie people choose to heat their homes if the weather is sufficiently cold - and not save on bills.
- Should gas prices decline again in real-terms, it is not known whether the recent downward trend in domestic gas demand would reverse.
- Ofgem (July 2009) undertook some initial analysis, but it may be possible to gain a deeper understanding of the price elasticity of GB household gas by a more detailed desk-analysis of the trend in household gas demand against prices, adjusting for external temperature, improvements in efficiency etc – say for the period 2000 to 2010 (ie including winter months 2009/10).

6.3.1 Options for reducing household gas use and associated carbon emissions

Turning down thermostats (true for electricity as well as gas) - Residential buildings account for 54% of all heat consumption in the UK. Modelling carried out for the Energy Saving Trust by the Building Research Establishment indicates that a 1 degree celsius turn-down of the central household thermostat achieves a 10% lower heating requirement for either gas or electric heating for a range of different dwelling-types (3 bed-semi, terraced, detached and flat) – down to a temperature of 16 degrees celsius, whereafter the expected savings diminish[56]. This is important insofar as it potentially offers material savings on fuel bills, offers potential economic savings across both the gas and electricity systems, and, potentially, with respect to gas, oil, and the relatively few remaining coal-fired boilers, could offer additional and significant household carbon savings – provided consumers are able or willing in practice to turn-down their thermostats. The first progress report of the Committee on Climate Change picks up the findings of the EST modelling[57], stating that 'turning down thermostats is probably the easiest and cheapest way to achieve substantial CO2 reductions'. The CCC estimated that turning down thermostats by 1 degree Celsius could reduce carbon emissions by 5.5MtCO2 per annum[58].

Heating Controls - The CCC identifies lack of effective heat controls as a key barrier to unlocking potential energy and carbon reduction and indicates that 10 million homes lack some or all standard heating controls such as programmeable timers, room thermostats and thermostatic radiator valves, and, additionally, that analysis by the Market Transformation Programme had suggested that a substantial proportion of householders do not set their controls properly. Element Energy for the CCC identify a technical potential from better controls of 2.2 MtCO2 pa (mainly room-thermostats)[59]. Difficulty in using controls, and in particular, setting boiler clocks and timers, is a key factor in energy waste. If consumers can be persuaded to turn-down thermostats (as above), then better controls (automated or not) allow fine-tuning in cooler or warmer weather.

Boiler Replacement - An A-rated condensing boiler can use up to 30% less fuel than an old boiler to provide the same amount of heat[60]. In 2005, 18.4 million homes did not yet have condensing boilers. Household boilers are replaced / installed at an estimated rate of 1.6m boilers pa. The CCC hope to see 12 million boilers replaced by 2022, thereby, via normal rates of boiler replacement, hoping to save around one third of achievable household carbon-dioxide[61]. A boiler scrappage scheme announced in the Pre-Budget report on 9 December 2009 to bring forward replacement of 125,000 old inefficient G-rated boilers acknowledges the potential benefit.

Bio-Gas - Estimates vary on the technical potential for carbon abatement from injecting renewable bio-methane into the gas grid for household use. At the low-end, estimated annual emission reductions of 1MtCO2 pa by 2022 are indicated (5.7 TWh). In the middle-range, the DECC Renewable Energy Strategy estimates technical potential for bio-gas at around 10-20 TWh and 2-4 MtCO2 by 2030 – with considerably higher estimates from E4Tech for DECC and Ernst and Young for National Grid.

6.3.2 Conclusions on gas price responsiveness

363 TWh of gas was consumed by households in 2008, equating to emissions of around 67 MtCO2. An estimated 2% annual energy saving by 2020 from better feedback from smart meters (including, say, the effect of demand-reduction incentives in gas tariffs) could therefore, in very approximate terms, be expected to deliver a 1.3 MtCO2 pa saving. Separately, taking the potential for household CO2 savings by the early 2020's identified above by the CCC from other boiler-related measures (in extremely approximate terms : thermostat turn-down by 1 degree C ~5.5 MtCO2 pa ; improved boiler controls ~ 2.2 MtCO2 pa ; and boiler upgrades ~9.1 MtCO2 pa), and, taking no account of additional energy and carbon savings which may be achievable from additional physical improvements in thermal insulation, it may be possible to expect savings in boiler-related CO2 emissions from households of the order of, say, one-fifth to one-quarter by 2020 against 2008 levels (albeit a significant 'health warning' is needed on any such estimate, given the scope to double-count potential savings from each of these different measures). Prospective carbon savings from smart meters look relatively modest against potential savings from these other boiler-related measures. However, importantly, by offering householders better feedback and stronger signals about their gas use and spend, consumers could become more open to making savings by opting for these other measures.

For the foreseeable future, reducing household gas consumption is therefore likely to be the single most effective available measure to reduce household carbon emissions in the home (more efficient boilers, better controls, thermal insulation, feedback on usage). Price incentives and tariffs from smart meters may have a limited role in support of these other more direct measures.

Longer term into the 2020's bio-methane injection should achieve some de-carbonisation of household gas depending on the rate of development.

Potential economic savings from reduced household gas-use will be important for households and companies alike, given expected continued upward pressure on gas prices in the future.

6.4 Great Britain household electricity use and potential price response

In 2007, UK households accounted for 35% of final electricity consumption by sector[62]. Domestic electricity demand doubled in the period to 1970 to 2007, and in the first part of this decade continued to grow at around 1.5% pa.

Around 28 % of household electricity can be assumed to be consumed by electric space-heating and water - and around 72 % (estimated at 85.3 TWh in 2009) assumed to be consumed by domestic electrical appliances including cooking and lighting[63].

In 2006, around 5 % of UK space heating was electric (final consumption). Of this, most was off-peak storage heating. Around 13 % of water heating was estimated to be electric in 2006 (presume including showers), and it seems fair to assume that a similar proportion (ie say 5-6 %) may also be off-peak[64].

Recent real-terms price increases for electricity between 2005 and 2007 suggested a very modest electricity demand reduction in 2007 – but materially less than for gas (Ie this demand switched off – did not shift (no price signal)). In 2008, despite real-terms price increases, demand for domestic electricity rose by 2.4% (from 115TWh to 118TWh) and this is believed to have been cold-weather related[65].

The chart at Annex 2 gives a breakdown of estimated UK household electrical appliance use in 2009. Some usage is likely to be more price-responsive and 'discretionary' than others and our initial conclusion is that around one-fifth to one quarter of household electrical appliance load could be price responsive (excludes heating and most direct water heating (most already off-peak).

6.4.1 Pre-2020s

- **Lighting, small appliances and consumer electronics –** dramatic growth in the past twenty years, now accounting for around 15% of all domestic energy consumption – and around half of all electrical appliance load in the home. However, much of this load is unlikely to be very time-flexible and therefore may offer relatively little price response – albeit some savings potential available from turning off. The Chart in Annex 3 shows the likely impact of product standards between now and 2020. This strongly suggests that product standards, not tariffs, are likely to have a far more material impact on electrical usage from lighting, small appliances, consumer electronics, stand-by and ICT – both before 2020, and afterwards[66]. (See Table at Annex 3).

- **White goods** (ie wet appliances and refrigeration) – product standards have already had a positive effect on efficiency and this trend can be expected to continue[67]. Wet appliances are potentially price-responsive and represent ~17% of estimated household electrical appliance load. Refrigeration (also ~17% of estimated household electrical load), could also become responsive – but to some extent uptake rates for automation is more likely to be driven by domestic appliance stock turn-over, rather than retrofit. Electric showers may be price-responsive to a degree.

6.4.2 Post-2020s

Key questions in respect of development of new and / or additional household electrical load for the 2020s' are :

- How much additional electrical load might be expected and from what appliances;
- By when this new load is likely to materialise ;
- How much of this new load will be *price-responsive* – ie either have a storage capability and / or able to respond to a price-signal or automated control *at a time / moment when flexibility can offer economic value to the electricity system*
- How might this new load impact on parts of the electricity system – eg on generation requirements, system operation, and on the networks (especially distribution networks).

6.4.3 Future developments in responsive household electricity

- **Electric cars** – There are a range of estimates for uptake rates of electric vehicles. The Climate Change Committee anticipate a combination of plug-in hybrid and battery cars of 240,000 by 2015 and 1.7 million by 2020 amounting to ~7-10% of new car sales in 2020, (some studies suggest a far more optimistic upper range, up to 20% of new car sales in the early 2020s[68]). Time-of-day flexibility is expected in charging, with the assumption that most charging takes place overnight or at other low-cost periods, and therefore price-responsiveness assumed. In practice, the extent of charging at low-cost periods will in part be shaped by eventual balance between trickle-charging over long periods (say 3kW) against booster-charging over short periods (say 50kW). Electric vehicle batteries may also offer a storage and 'export' capability, also likely to be price-responsive.

- **Electric Heat** – NERA for the CCC[69] assess Renewable Heat Technologies and likely uptake rates. For heat-pumps (air-source and a modest contribution from ground-source) they assume a central estimate of around one-million household retrofits of Air Source Heat Pumps in England installed by 2020 (1.2 m for UK[70]), resulting in an extra peak-load of 3GW and possibly with significant location-specific reinforcement implications for networks[71]. Low uptake rates of this order (say 100,000 per annum) are considered realistic, due to present costs, suitability and performance of heat-pumps in the existing housing stock. Without major technical improvements, or, major thermal adaptations to the existing housing stock, heat-pumps are most likely to be installed initially in UK oil-heated homes off-the-gas-grid ((~9%) of which one-third may be unsuitable because older, solid-wall properties) ; in the post-2000 housing stock (total 2 million homes in UK), or, in new homes (say potentially 2 million new homes expected by 2020). These estimates do not assume replacing existing off-peak storage heating with heat-pumps. Three important points : first, current types of heat-pump do not necessarily involve a heat-store (albeit some do). Without either storage or some alternative 'top-up' at peak (eg natural gas) heat-pumps are likely to have a winter peak demand profile – and so may offer only limited price-response at peak (but could be price-responsive at high-priced low-wind periods or at critical peaks with automated response, like air conditioners in US) ; second, as noted above, heat-pumps would appear to contribute very significantly to creating *additional* peak-load – potentially creating a new and major need for peak-related investment in power plant and the networks ; third, what prospects for development of alternative and new forms of electric storage heater[72] .

- **Refrigeration**[73] – technical trials are being set up on the potential for highly-flexible price-responsive 'services' via automated switching which fridges and freezers could offer if appropriately equipped[74] :
  - Frequency response support to system operator in maintaining the system within the statutory frequency limits of plus/minus 0.5% of 50Hz (operational limit +/- 1%) by having an automatic capability to cut-in and out in response to second-by-second fluctations in system frequency.
  - Remote load-switching (eg radio teleswitch).

6.4.4 Conclusions on household electricity price responsiveness

It was noted in Chapter 4 above that 'additional' carbon savings are unlikely to be available for carbon accounting purposes from either electricity savings or from electricity peak shifting because electricity emissions are already capped upstream under the EU ETS. However, there will be security of supply and economic benefits from electricity savings and peak shifting (see Chapter 4 and para 6.5 below for detail).

The following key points emerge in respect of characteristics of GB household electricity use and likely price-responsiveness :

- **Pre-2020, growth in UK household electricity load will continue to be dominated by lighting and appliance-use.**

- **Pre- and post 2020, improved product standards should be the main tool to slow the present rate of household electricity demand growth.**

- **Pre-2020, tariffs may have a role in :**

    - **Peak-or load shifting insofar as household electrical appliance-use proves price responsive** – i.e. probably wet appliances, and perhaps some showers, chargers and lights **– but this may be limited.**

    - **Demand reduction – insofar as there is waste in household electricity use.**

- **In the 2020's there will be significant economic value from flexibility in the electricity system – but new and significant electrical load (which does not exist today on the household side) will be needed to take maximum advantage. Failing this, most flexibility may continue to be provided via the supply-side, including potentially from peaking fossil generation plant and / or embedded generation or microgen.**

- **There will be some development of electric cars and heat pre-2020, but substantial new household electrical load from cars and from heat is likely only well into the 2020's, by which time the electricity system should be increasingly de-carbonised.**

- **Cars and refrigeration may be price-responsive and may offer off-peak or load-following services. Electric heat may be less price-responsive, unless it can be repeatedly switched on and off, and / or has a thermal storage capability. In addition, without storage, heat pumps may very considerably push up the costs of peak-related generation and network provision.**

6.5 Potential value of available economic and carbon savings from household demand response

DECC GB Household Meter Impact Assessment

The GB Meter Impact Assessment includes a range of estimates for potential economic and carbon savings from smart meters[75]. Values for all estimated benefits to the end of 2030 in the DECC Central Communications Model (Option 2 – central case), including the consumer benefits, are indicated in the right-hand column in the Table below.

Table : DECC GB Household Meter Impact Assessment

Central Communications (central case in £ million pv) – DECC Impact Assessment*				
Total Costs - £8,641 bn pv		**Total Benefits - £14,622 bn pv**		
Capital	£3,509 bn	**Total Consumer Benefits - £6,990**		
Installation	£1,539 bn	**Energy saving** ~£28 pa saved per customer on a £1,000 annual dual-fuel bill **Electricity Saving –** 2.8% saving per customer* **Gas Saving** 2% saving – credit. 0.5% pre-pay	**Energy saving – £4,464 bn ~ 30% of total Benefit** of which : **Electricity saving - £2.5 billion** ~ 17% of total Benefit **Gas saving – £1.9 bn** ~13% of total Benefit	
O&M	£623 m	**Load Shifting**	£617 m	4.2% of total Benefit
Comms upfront	£710 m	**ToU Tariffs - Electricity** – assume 20% uptake - (central est) - gives 3% bill-saving overall for these 1-in-5 customers - & a 5% peak reduction.	£358 m	2.4%
Comms O&M	£942 m	EU ETS Savings (Electricity)	£460m (15MtCO2)	3.1%
Energy	£547 m	Global CO2 reduction (Gas)	£896 m (24MtCO2)	6.1%
Disposal	£39 m	Reduced losses	£194 m	1.3%
IT	£42 m	**Total Supplier Benefits - £6,272 bn**		
Pavement reading inefficiency	£284 m	Avoided meter reading	£2,662 bn	18%
Legal & contractual	£406 m	Inbound inquiries	£957 m	6.5%
		Customer service overheads	£166 m	1.1%
NPV	£5,981 bn	Debt handling	£976 m	6.7%
Average annual impact per meter (£)	4.7	Avoided PPM COS premium	£906 m	6.1%
		Remote (dis)connection	£222 m	1.5%
(Stranding costs)	£755 m	Avoided site visit	£383 m	2.6%
		Other benefits - £1,361 bn		
		Reduced losses (networks).	£194 m	1.3%
		Reduced theft	£103 m	0.7%
		Microgeneration	£33 m	0.2%
		Customer switching	£1,031 bn	7%
Source – Impact assessment of a GB-wide smart meter roll-out for the domestic sector. DECC. December 2009. p.44. Option 2 – Mandated roll-out of smart meters under the centralized communications model by the end of 2020. *Note - 5% of 2.8% saving attributed to expected savings from IHDs issued under CERT without smart meters				

The Impact Assessment sets the £8.6 billion (pv) estimated cost of investment under the central communications model (central case) for a GB household smart meter roll-out against the potential of total estimated cost savings of £14.6 billion (pv).

Of the £14.6 billion estimated value of total benefits to the end of 2030, around half (£6.2 billion) are benefits to suppliers (with a small proportion for other market actors), and, almost half are attributed as a direct benefit to the customer (£6.9 billion). As the Table shows, these potential customer savings stem from several sources.

By far the largest element of the customer saving benefit (and also the largest single benefit by some margin) is the £4.4 billion attributed to customer energy savings – around one-third of the total expected £14.6 billion saving. The underlying assumption is that these savings are realisable largely as a result of improved feedback afforded by smart meters. Additional total savings of around £1 billion are also identified : load-shifting - £617m ; peak-shifting and energy savings resulting from time-of-use tariffs at an assumed 20 percent up-take (in addition to existing off-peak Economy 7 & 10 usage) - £358m.

The estimated energy savings - 2.8% (electricity) and 2% (gas credit ; 0.5% gas pre-pay) – may well be achievable – but will be highly dependent on customers responding to consistent and sustained supporting advice and information, to ensure high customer awareness. Savings at these levels are expected by DECC to give an overall saving of ~£28 pa per customer on a £1,000 annual dual-fuel bill.

Brattle Group estimates for available economic and carbon savings from household demand response.

Over time, the kinds of smart tariff discussed in this report could also be expected to deliver some additional savings over and above those already identified in the DECC impact assessment.

With the help of Brattle, we have brought together material from the government impact assessment with other material on energy-use, including that from the Committee on Climate Change (as discussed earlier in this Chapter), to develop our own rough estimates of the economic and carbon potential from GB household demand response both before 2020 and through to 2030. These are shown in the Table below.

In producing these estimates, we have relied heavily on:

- The projections of domestic consumers' bills produced by Ofgem for its Project Discovery[76], and
- The scenarios for power generation[77], the uptake of electric vehicles[78] and the uptake of renewable heating options[79] published by the Committee on Climate Change.

Further details of the calculations and assumptions underlying the results presented in the Table below can be found in Annex 4. In brief, we have made the following assumptions:

- Smart meters – in due course lead to a greater uptake of both electric vehicles and heat pumps (as a replacement for oil heating) than would otherwise be the case but no attempt is made to quantify what impact this increased electricity demand might have on prices. In other words, only volume effect is measured, not price.

- Energy savings estimates – assumed from smart meter 'feedback' using DECC estimates (electricity 1.5% - 4% ; gas 1-3%). For peak electricity, a range of 1.5%-4% peak reduction is also assumed. Savings from automatically controllable load (either with or without a smart meter) are not included due to lack of suitable data.

- Network charges : electricity transmission and distribution charges - for a given level of demand reduction in a customer's demand (say, 2.8%), the proportion attributed to reductions in electricity transmission and distribution charges is assumed to be significantly less (for example, say, 1.3% where demand reduction is 2.8%[80]) ; gas transmission and distribution charges – no cost benefit assumed from reduced gas demand (gas pipes sized to peak and household demand saturated).

- Environmental initiatives - For reductions in electricity demand, we assume that there will be a cost-saving due to reduced obligations . For the Renewables Obligation a one-to-one reduction in demand and costs assumed. For the EU ETS the consumer benefit is assumed to be included in the reduction in wholesale energy costs. However, for those environmental initiatives requiring a target-level of revenue, we assume no cost-reduction arising for either electricity or gas from reduced demand. This is on the assumption that any demand reduction would need to be offset by higher per unit charges (eg for CERT, CESP, FITS, RHI, CERT, smart meters, CCS levy).

- Treatment of CO2 emissions from electricity generation - in line with the DECC / Treasury guidelines[81] that the impact on CO2 emissions from reductions in electricity consumption (whether overall or at peak) should be measured using estimates of the marginal intensity of electricity generation. However, we have explored a range of scenarios for carbon intensities and traded carbon prices, rather than simply relying upon the DECC / Treasury values.

Estimated Economic and Carbon Potential from Household Demand Response to 2030 (Source – Brattle Group Modelling – see Annex 4)				
Effect	**Results**		**2010 – 2020**	**2021 – 2030**
Electricity Demand Reduction	Customer Benefits	£ million PV	520-1,400	1,000-2,650
	CO2 Savings	Mt CO2 £ million PV	5-16 MtCO2 115-370	7-18 MtCO2 150-430
Electricity ToU Tariffs / Load Shifting	Customer Benefits	£ million PV	<130	<270
	CO2 Savings	Mt CO2 £ million PV	0.4-1.7 MtCO2 9-40	0.4-1.8 MtCO2 10-45
Gas Demand Reductions	Customer Benefits	£ million PV	450-1,350	700-2,150
	CO2 Savings	Mt CO2 £ million PV	4-13 MtCO2 180-545	8-24 MtCO2 300-890
Fuel Switching (Electric cars; and oil to heat pumps)	Customer Benefits	£ million PV	140-400	1,100-4,000
	CO2 Savings	Mt CO2 £ million PV	0.5-1.0 MtCO2 <30	3-22 MtCO2 60-525

Our analysis broadly indicates the following with respect to economic and carbon potential pre- and post-2020 from household demand response :

- **Electricity demand reduction benefits** – available economic savings grow as smart meters are rolled out – and effectively double post-2020. Electricity demand reduction does not offer additional carbon savings for the purposes of carbon accounting due to the EU ETS cap. However any electricity demand reduction does give additional economic savings in respect of meeting the UK share of the EU ETS and Renewables obligations at lower cost.

- **Electricity peak / load-shifting** - the economic benefit of electricity household peak response, relatively modest as of today, could double in the 2020s as meters are rolled out. Potential range of peak-reduction assumed is 1.5% - 4% given the characteristics of household electrical load today. For peak load shifting, Brattle has not attempted to take account of foregone or delayed investment in peak power plants and this probably accounts for the lower benefits than those found by DECC.

In the 2020s, against a much higher potential household electricity demand than today, with new price-responsive electrical load available (seemingly not included in the DECC Impact Assessment), from electric cars and possibly from heat - then the potential economic value in peak- and load-shifting and associated cost-savings could increase significantly (probably more new load than the Table suggests). Electricity peak/load switching does not offer additional carbon savings for the purposes of carbon accounting due to the EU ETS cap.

- **Fuel-Switching to electricity** – a significant economic benefit could arise in the 2020's via electrification of cars and heat, by associated reductions in carbon emissions from uncapped transport- and heating-fuels (assumed oil-heated homes initially). The DECC Impact Assessment does not expressly incorporate fuel-switching. Fuel switching delivers additional carbon savings as the fuels switched from (notably oil and gas) are not under the EU ETS cap.

- **Gas savings** - from improved feedback gives both economic savings and carbon savings both pre- and post-2020. These increase over time as meters are rolled out and are assumed to remain at around 2%. The DECC Impact Assessment does not consider the impact of gas tariffs or incentives for gas demand reduction, but some additional demand reduction could also be expected in due course to be achievable from these (ie over and above the 2% assumed from feedback). Potential savings from feedback and tariffs are distinct from potential household gas savings likely to be achievable from improved insulation, boiler upgrades and better controls. These latter measures may well achieve additional savings – but by reducing gas-use per household, could perhaps over time dampen scope for additional savings from gas smart meter feedback and price reduction incentives.

Conclusion on potential value of available economic savings from household smart-tariff related demand response

Ofgem have indicated that the estimated energy savings identified in the impact assessment, are a priority for delivery in terms of justifying the public policy aspects of the smart meter mandate[82]. We agree with this. We also take the view that these savings are only likely if concerted action is taken in support. A list of measures is proposed in the recommendations to support delivery of these core smart meter energy savings.

Second, smart tariffs as explored in this paper could bring additional savings – both peak electricity and load-following, and overall electricity and gas savings as identified above. However, these additional savings, including the public policy potential (carbon, security of supply, cost-savings) are perhaps unlikely to be realised without the measures identified below in the recommendations being first put in place.

7. Recommendations : commercial and regulatory and public policy

The recommendations in this part of the report are split into two main areas : commercial and regulatory ; public policy.

7.1 Commercial incentives and regulatory issues for market actors

This study has examined potential impacts in the energy supply chain and on customers of developing household demand response through load-control and new tariffs. This will be relevant to how the economic and carbon potential of household customers might be realised in a world of smart grids and smarter gas networks. Initial development of household demand response is most likely for electricity, (although some smart gas controls may also be developed in the near future). There are a number of commercial and regulatory factors that will affect incentives for different market actors and which will need to be addressed to realise the scope and potential for household demand response. Some recommendations in these areas follow. DECC, Ofgem, and the energy companies, (including energy service companies), will need to undertake further detailed work on all these areas.

- **Projects under the Low Carbon Networks Fund and under the Innovation Funding Incentive under the distribution price control, need to test out prospective commercial and contractual arrangements and customer incentives for demand response, including at a household level. These funds should not simply bring forward technical trials.** Projects that come forward under the new £500 million Low Carbon Networks Fund will therefore need networks and suppliers as central partners and will also need to work with others such as generators, shippers, aggregators, other third parties and local communities. DNOs and their partners should explore and develop projects which will fully test commercial and contractual aspects, including the impacts of new time of use or demand response tariffs on customers, suppliers, networks, generators, shippers, and third parties. **Non-commercial findings from LCNF and IFI projects should be made generally available so that lessons are shared. Ofgem should consider such projects a priority -** in particular to better understand :

    - the nature and formality of agreements likely to be needed between suppliers and their customers to deliver demand response – and how these may sit with the requirements of a competitive market.

    - the practical implications for suppliers where third parties (DNOs, ESCOs, aggregators) are directly involved in delivery of household demand-response

  - the potential for double-counting of benefits – ie the way in which demand-side services (and benefits) may need to be prioritised between suppliers, DNO and system operator.

- **As parties to the statutory Distribution Level Codes the industry should consider the need for changes to Network Connection Agreements and to Distribution Use of System Charges to make these more responsive to demand-side actions. Ofgem will also need to actively engage, including ensuring that demand-side actions are enabled as part of the smart meter implementation plans and the proposed new Smart Energy Code**. In particular, it will be important to recognise potentially significant value in the future of locational benefits ; to consider how to make network charging arrangements more responsive – so that suppliers and others can be rewarded appropriately for any demand-side actions they take. Similar network Code issues and charging arrangements able to reflect 'negawatts' are currently being explored in respect of embedded and micro-generation.

- Network charges are at present bundled together with the retail tariff and not separately identified. If far more peak-related network investment is required in the 2020's, DNO costs could in time become a more significant proportion of the end-bill. **To improve understanding and transparency, there may in time be merit in considering the case for displaying network charges separately to the end-customer. This may also tie in with financing measures under discussion in respect of renewable heat and microgeneration.**

- **Similarly, as parties to the statutory arrangements and Codes for Settlement, the industry will wish to consider the need for change – including the present deemed profile arrangements - to enable suppliers to capture more readily the full economic benefit of any demand-side investment they make for their customers and to avoid competing suppliers from obtaining the benefit. Again, Ofgem will wish to ensure appropriate links to smart meter implementation plans and proposed new Smart Energy Code.**

7.2 Public policy benefits.

Smart tariffs will form just one part of a range of measures that should impact on household energy demand. In the period to 2020, there will be substantial new demand-side investment - on insulation, renewable electricity and heat, on smart meters and smarter networks. At present, it is not clear how these separate policy streams are to be integrated at a householder level - although the forthcoming Home Energy Management Strategy - (HEMS - due for publication in March 2010) - should set out thinking on coordination. **Given that much of the very substantial demand-side investment will ultimately be funded by customers, DECC, supported by Ofgem, should make sure through good programme coordination, that the various incentive schemes are actively brought together in such a way that the 'whole' in the end adds up to be more than the sum of its parts.**

The government mandated the £8 billion smart meter investment for households after lengthy consideration of the costs and benefits. Estimated energy savings from smart meters (in which smart tariffs would play a part) represent nearly one-half of the total estimated smart meter benefit, and by far the single greatest element of the customer benefit. Over time smart tariffs could also deliver some additional savings over those identified in the impact assessment. However, realisation of this potential will depend very largely on how consumers respond to feedback on their energy use as well as to new price incentives to shift or reduce demand (including developments in automated load-control) which the companies will offer.

The potential public policy benefits from new tariffs and price packages for households- peak, load-following and overall demand reduction - are only likely to be realised in the context of a wider integrated strategy for the household sector. **Ofgem and DECC should therefore identify :**

- **What actions, in addition to the offer of an IHD (in-home display), could help realise the estimated £4.4 billion saving for household gas (2%) and electricity (2.8%), identified by the impact assessment.**
- **How to ensure full integration of the smart meter roll-out with the other major household demand-side programmes.**
- **What to monitor and measure in any post roll-out evaluation. Whether the estimates for energy savings in the Impact Assessment, (while not a goal or target as such), are a suitable benchmark against which to judge success in delivering the public policy aspects of smart meters.**
- **How any post-2012 obligation framework (should there be one) for suppliers or others, would link to the new capability for accurate measurement of carbon or energy savings afforded by smart meters.**
- **Whether a new energy saving obligation on suppliers would help to ensure that new supplier marketing activity facilitated by smart meters (eg cross-selling of communications, insurance, financial, security etc) did not take place at the expense of realising the original public policy goal of energy saving, and as envisaged by the smart meter mandate**

Energy Demand Research Project

- **Detailed findings from DECC's Energy Demand Research Project (EDRP) should be made available as soon as possible to improve the available information on the realisable potential for household demand response, which will help to inform the development and design of tariffs.** DECC and Ofgem should aim to maintain an overview of GB smart meter pilots and trials (EDRP or not) and encourage sharing of non-commercial findings. DECC should consider using their UK energy statistical data to undertake an analysis for Energy Trends of the historical relationship between GB energy retail prices and weather-corrected household gas and electricity demand, including regional differences.

Rising Block Tariffs for Environmental Costs

- Rising block tariffs for electricity and gas would not be straightforward to introduce in the GB retail market and there are some other important issues to be addressed (notably distributional impacts). However, the principle of rising block charging for energy could have potential for application to the environmental costs charged to gas and electricity bills. Customers would be incentivised to reduce their overall energy use to some degree and high-users would pay a higher proportion of these costs. **Further work on applying a rising block principle to the environmental costs of energy bills is warranted, especially given the scale by which this part of the customer bill is likely to rise by 2020. Specific consideration needs to be given to the potential issues for low-income or vulnerable users with high and inflexible energy consumption patterns.**

8. Conclusions

Energy saving forms nearly one-half of the total estimated benefit from the GB household smart meter roll-out. Together with improved feedback, as this report has shown, smart tariffs and other price incentives for households, could help to deliver energy bill savings to customers, economic benefits across the energy supply chain and contribute to the public policy goals of carbon emissions reductions and security of supply. Such tariffs could help to reduce both peak and overall demand, but there are many consumer and cross-industry issues to consider.

Customers will judge introduction of smart tariffs on the benefits to them in terms of : impacts on their energy bills; how they impact on low income / vulnerable consumers; comparability of tariffs and avoiding undue complexity. Not 'shock' bills. There is much scope for suppliers to develop new offers for customers but some new customer protection measures are likely to be needed to ensure customers do benefit. In the long-run, willing participation by customers will be key to successful delivery of GB household demand-response.

The scope for and potential benefits of household demand and peak reduction are not static and will change pre- and post-2020s. For the foreseeable future, reducing household gas consumption is likely to be the single most effective way of reducing household carbon emissions in the home. This suggests that a main policy focus for the near-to-medium term should be on better insulation, improvements in heating controls and boilers and encouraging behaviour change. Price signals and tariffs will have a part to play, together with improved feedback on usage patterns, in incentivising householders to turn-down thermostat settings – but in most homes the physical measures (insulation, efficient boilers, better controls) will first need to be in place to make thermostat turn-down a practical and sustainable reality. It is crucially important that these physical improvements are made as soon as possible in the homes of vulnerable and low income consumers, so that smart meters and smart tariffs do not contribute to more of those households under-heating their homes. This should be a key issue for the Home Energy Management Strategy, as well as developing measures for able-to-pay households.

There is much interest in developing a more responsive electricity demand side (and the role of tariffs in this) because demand-side flexibility may have the potential to keep down costs as the electricity system decarbonises. At present both the economic value of demand-side flexibility to the electricity system and the scope in the household sector for such demand response may be rather modest, given current patterns of GB household electrical appliance use. In the short term, therefore, it may be more realistic to focus on the commercial sector for electricity demand response. Nevertheless, this report has shown that there are many steps to be taken to realise even the modest household potential that exists today. Importantly, many of these practical and commercial issues need to be addressed now in order to facilitate realisation of the potential economic benefits of household demand flexibility for the longer-term.

Assuming significant take-up of electric cars and new forms of electric heating in the longer term, the potential for household demand flexibility should increase. However, new forms of electric heating (i.e. heat pumps) will need an off-peak or storage capability, and / or a price-responsive load-switching / load-following capability, if that new heating load is to provide demand-side flexibility rather than add to peak load. From a customer point of view, the transition to electric cars and heat is only likely to be affordable if these appliances can be mostly charged at low price periods - and so successful development of household automation and load-switching will be essential.

Automation and load switching (for peak response and for load-following) could potentially have a significant role. Automation and load switching are not dependent upon smart meters, but they will be greatly assisted by the accurate measurement and scope to provide new tariffs and price incentives that smart meters will bring. This will also tie into smarter network development.

Realising the potential for household demand response and the role of smart tariffs in helping to deliver this will also require much further work on the interactions between different actors in the electricity and gas supply chains and also on what price responsive load will be available in the future. There is a need to develop commercial relationships and regulatory mechanisms to align incentives and structure appropriate agreements between the parties.

Endnotes

[1] H M Government. The UK Low Carbon Transition Plan. National strategy for climate and energy. July 2009.

[2] DECC. Impact assessment of a GB-wide smart meter roll-out for the domestic sector. December 2009.

[3] Ofgem, 2008. Energy Supply Probe – Initial Findings Report.

[4] Ibid.

[5] Ukpower.co.uk, November 2009

[6] There are many approaches to fixed and variable cost-recovery in household energy tariffs in other countries. In some places, network charges are separately identified**.** There are also some examples of rising ('inclining') and reducing ('declining') block / stepped tariffs, in countries and states that have regulated household retail tariffs – including some examples which combine inclining block tariffs in summer and declining block in winter.

[7] Digest of UK Energy Statistics (DUKES) – July 2009. Chapter 5 – Electricity. para 5.25 p.120.

[8] Useful references include : Ofgem Discussion Paper 'Can Energy Charges Encourage Energy Efficiency?' July 2009 ; Ahmad Faruqui and Sanem Sagici. The power of experimentation. New evidence on residential demand response. Brattle Group, May 2008; Faruqui A and Wood L . Quantifying the Benefits of Dynamic Pricing in the Mass Market. Edison Electric Institute. Jan 2008; Sustainability First and Engage Consulting Limited. International Smart Meter Trials, Selected Case Studies - Smart Tariffs and Customer Stimuli, May 2008 ; St Vincent de Paul Society. Customer Protections and Smart Meters. Background Paper and Issues for Victoria. Gavin Dufty and May Mauseth Johnston. August 2009.

[9] Karen Herter, Residential implementation of critical-peak pricing of electricity, Energy Policy, Vol 35, Issue 4 April 2007.

[10] Ofgem Consumer First Panel. Research Findings from the Third Events October 2009

[11] As detailed in reference 4 above.
[12] NIE Time of day trial report. April 2005

[13] Karolien Verhaegen, Leonardo Meeus and Ronnie Belmans. The influence of public service obligations on distribution network tariffs. Katholieke Universiteit Leuven. 2006

[14] Herter. Op cit.

[15] Hydro One Networks Inc. Time-of-Use Pricing Pilot Project Results. EB-2007-0086. May 2008.

[16] For example : Freeman Sullivan and Co. 2008 Load Impact Evaluation for Pacific Gas and Electric Company's Smart Rate, Smart AC and Residential ToU Programs. May 2009 ; Chris King E-Meter. PowerCents Trial. Barcelona. October 2009; Smart Meter Consumer Impact. Initial Analysis. A Report to the Ministerial Council on Energy Standing Committee of Officials. Energy Marketing Consulting associates (EMCa). Analysis for Integral Energy and Energy Australia. April 2009.

[17] DECC, 2009. Delivering secure low carbon electricity. A call for evidence. p.50

[18] NIE Time of day trail report. April 2005

[19] Karen Herter, Residential implementation of critical-peak pricing of electricity, Energy Policy, Vol 35, Issue 4 April 2007)

[20] Correspondence with Susan Frank, Hydro One Inc. November, 2009.

[21] BRE. An investigation of the effect of rising block tariffs on fuel poverty. Committee on Climate Change, October 2009
See also earlier reports on distributional aspects of Increasing Block tariffs by Centre for Sustainable Energy : 'Towards Sustainable Energy Tariffs : a report to the National Consumer Council' (2008) and 'Waste not, want not : energy tariffs for sustainability. A report for WWF UK'. (2007).

[22] Ofgem. Project Discovery. 9 October 2009. £200 bn of new investment by 2020 – security of supply, infrastructure and low carbon transition – possibly representing a range of 14-25 % increase on end-prices to customers. Some working estimates suggest a household dual-fuel bill by 2020 of £1800.

[23] Op cit : Freeman Sullivan and Co. 2008 ; Chris King E-Meter. PowerCents Trial. October 2009; Energy Marketing Consulting associates (EMCa). April 2009.

[24] DECC Consultation Impact Assessment of Smart Metering Roll-Out. December 2009. (Central Comms, Central Estimate). Assumes (mid-range) a 20% take-up of a ToU tariff, and assumes a 3 % overall electricity bill reduction and a 5 % peak-use reduction (p.25)

[25] DECC Smart Meter Impact Assessment – assumes 2.8% electricity saving from improved feedback on usage.

[26] DECC Smart Meter Impact Assessment – assumes 2% gas saving from improved feedback (0.5% from gas pre-pay).

[27] Herter, Op.cit.

[28] Herter. Op cit.

[29] Illinois Public Utilities Act, 2006 and also Chris King. EMeter Consulting presentation to Metering Europe conference Barcelona. 7 October 2009

[30] 'The smart way to display' . Energy Saving Trust. October 2009.

[31] Material in this section draws on discussion and consultation with our sponsor group and with other colleagues at National Grid, Ofgem, DECC, ENA, ERA, EATechnology (Jen Carter & Linda Hull – IEA DSM secretariat).

[32] DECC. Impact Assessment of a GB-wide smart meter roll-out for the domestic sector. December 2009. pp 25-26 and p.53. See also, DECC. 'Valuation of Energy Usage and Greenhouse Gases (GHG) Emissions for Appraisal and Evaluation, November 2009; DECC & DEFRA ' Making the Right Choices for our Future. An economic framework for designing policies to reduce carbon emissions'. March 2009. pp.34, 51 & 54.

If the UK out-performed its share of the EU ETS cap, UK generators might need to buy fewer carbon permits in the EU ETS, and this could depress the overall price of EU permits and the carbon price – resulting in some possible eventual blunting of the carbon price as an EU-wide incentive for low-carbon investment.

[33] Such estimates are complex and vary depending upon assumptions / inputs. These very rough numbers draw from both Ofgem's Household Energy Bills Explained (August 2009 - Ofgem website) and Ofgem Environmental Tariffs report. (July 2009) (p20).

[34] Electricity has a half-hourly pricing structure which can to some extent reflect the underlying costs of electricity system balancing. Hence, electricity prices which change throughout a day could, to some degree,

reflect underlying costs. Although household gas use has peak-related characteristics, (and therefore presumably some peak-related costs) these are not presently reflected in the commercial gas market arrangements, which provide for a single daily balancing price, because short term gas storage is available within-day (line-pack, safety monitors). Should gas market commercial arrangements change at some future point (eg say from daily to four-hourly resolution), then, unlike today, there could be a commercial incentive to develop *within-day* gas load-shifting for non-I&C customers. Settlement arrangements would also need addressing for suppliers to capture the benefit.

[35] IHS Global Insight – Demand Side Participation Report. July 2009 – seems to concur with this view. Para 6.1 says ''The price differential between peak and off-peak tariffs also reflects how distribution and transmission charges are applied…investment in the distribution and transmission infrastructure is not assumed to be significantly reduced by increased levels of DSM'.
Similarly, Frontier Economics 'The Role of Future Energy Networks' Report for Ofgem. September 2009 p.38 and p.42.

[36] December 2009 Meter Impact Assessment value - £194m

[37] Ofgem Project Discovery (9 October 2009) identifies ~£200 bn low carbon and security of supply related investment by 2020 - which they indicate could result in increases of domestic energy bills of 14-25% from 2009 levels by 2020 – with wholesale price spikes which could lead to an increase in domestic energy bills of 60% in the interim.

[38] Linda Hull. EA Technology Consulting. 'UK Approach to Settlement' Slides. IEA DSM workshop. Chester. 21 October 2009 www.ieadsm.org . Chris Harris Slides. RWENpower. Market Force / ASI Smart Meter Conference. London. 3 December 2009.

[39] Chris Bennett. National Grid Slides. Market Force / ASI Smart Meter Conference. London. 3 December 2009.

[40] Price Elasticity of Demand for Electricity : A Primer and Synthesis. Electric Power Research Institute. January 2008. Describes how the price elasticity of demand serves as a measure of how price-changes influence use – ie price-elasticity is a ratio estimator. It indicates the percentage change in usage attributable to a one-percent change in price. An elasticity of zero (or close to zero) would mean the consumer was insensitive or inflexible to price change. If the elasticity were equal to 1, then a 10 % *decrease in price* would induce a proportionate *increase in consumption.* An elasticity value of over 1 results in a *greater-than-proportional* response, and an elasticity value below 1 results in a *less-than-proportional* change (ie less response), assuming all other influences on energy use are held constant.

[41] EPRI, op cit.

See also : Quantifying the Benefits of Dynamic Pricing in the Mass Market. Ahmad Faruqui & Lisa Wood, Brattle Group for Edison Electric Institute. January 2008. A Survey of Time-of-Use Pricing and Demand Response Programs. July 2006. Energy & Environmental Economics report to the US Environmental Protection Agency. July 2006 ; Ofgem Discussion Paper 'Can Energy Charges Encourage Energy Efficiency?' July 2009. EPRI – Residential Electricity Use Feedback : A Research Synthesis and Economic Framework. February 2009.

[42] Household Response to Dynamic Pricing of Electricity – A Survey of the Experimental Evidence. Ahmad Faruqui and Sanem Sergici for EPRI & EEI. January 2009

[43] Building Research Establishment (BRE). Domestic Energy Fact File 2008. p.10

[44]Heating oils by 3-times in real terms.

[45] Fuel-oil by 41%.

[46] See 'Residential energy demand and the interaction of price and temperature: British experimental evidence'. Andrew Henley and John Peirson. Energy Economics 20 (1998) pp 157-171 for a good GB discussion about responsiveness of heating energy demand to temperature (drawn from empirical analysis of GB electric storage heating usage).

[47]For example : (1) slides from Ian Povey, Electricity North West Ltd (ENW). IEA DSM workshop. 21 October 2009. Chester. www.ieadsm.org Very small DNO pilot for commercial customer load-management – customer expectation was for a far higher compensation level (by around ten times) for offering load-control or for potential interruption than the available gain which ENW was able to offer based on the avoided cost of supply. And (2) Commercial Gas Sales – sales of interruptible gas in 2008 amounted to 31% - 7 % higher than in 2007 (DUKES. July 2009. p.98) – presumably in response to higher prices being offered for firm gas.

[48] The average temperature in UK homes rose from 13 degrees C in 1970 to 18 degrees in 2004 – which reflects the fact that more rooms are being kept warm. It takes 50% more energy to heat a house to 18 degrees than to 13 degrees C. National Audit Office. Programmes to Reduce Household Energy Consumption. July 2008 (NAO).

[49] Key sources : Digest of UK Energy Statistics. July 2009 ; Energy Trends. BERR – Domestic Energy Consumption in the UK – Sept 2008 ; NAO. Op cit. July 2008 ; Energy Saving Trust – Heating Your Home Efficiently. April 2009. Quantifying the Energy and Carbon Saving Effects of Water Saving EA & EST – August 2009 .

[50] Committee on Climate Change (October 2009) – 27% **includes** power station emissions. The UK Low Carbon Transition Plan – National Strategy for Climate and Energy (July 2009) indicates that energy used in homes accounts for 13% of UK greenhouse gas emissions. The DECC / DEFRA guidance document 'Making the Right Choices for our Future. An economic framework for designing policies to reduce carbon emissions' (March 2009) indicates that in 2006**, the residential sector – *minus traded ie end-use electricity* – was responsible for 85 MtCO2e - or 13% of total greenhouse gas emissions by source** (ie GHG - not just CO2).

[51] Energy Trends. DECC – Carbon Dioxide Emissions. March 2009.

[52] Energy Saving Trust (EST). 'Heating Your Home Efficiently'. April 2009. Presume gas plus other fuels.

[53] Up from one-quarter in 1970. Domestic Energy Consumption in the UK. BERR. Energy Trends. Sept 2008

[54] Average gas consumption 19,500 kWh pa (average heating bill – 17,614 kWh pa). Standard two-tier gas bill – 7p/kWh for 2680 units and 3p/kWh above that – total £691 annual bill; Electricity average ~4,300 kWh pa – 14p/kWh for first 900 units & 10p/kWh the remainder – total £466. Typical November 2009 two tier standard tariff prices. On this basis, annual gas bill one-third higher than electricity.

[55] NAO & Digest of UK Energy Statistics. July 2009. para 4.13. Domestic gas use up from 353 TWh in 2007 to 363 TWh in 2008. In January 2009, total daily maximum gas demand was 6.5% higher than 07/08 level (but 1.3% lower than January 2003 record). Retail gas prices rose by 75% and electricity prices by 54% between 2003 and 2007 – BERR – Energy Trends Sept 2008.

[56] EST website and private communication – July 2009.

[57] Meeting Carbon Budgets – the need for step change. Progress Report to Parliament. Committee on Climate Change. 12 October 2009. p.162

[58] CCC Report. December 2008.

[59] TACMA (The Association of Controls Manufacturers) estimate double this potential available.

[60] All new gas boilers must be high-efficiency A or B-rated. A to B-rated boilers have a conversion efficiency (ie converts fuel into heat) of at least 90%. G-rated (old, non-condensing boilers) convert around 65% of their fuel into heat. Energy Saving Trust. Heating Your Home Efficiently. April 2009.

[61] This potential is against a 2005 'reference'case (9.16 MtC02 saved against a total potential of 28.5 MtC02 pa), or against a more optimistic household carbon reduction scenario enabling potential savings of around one-quarter of potential (9.16 MtCO2 saved against 35.2 MtC02 pa potential Element Energy. Uptake of Energy Efficiency in Buildings. On behalf of the Committee on Climate Change. Final Report – August 2009.

[62] 116 TWh in 2005 ; 116.4 TWh in 2006 ; 115 TWh in 2007 and 117.8 TWh in 2008 . Digest of UK Energy Statistics 2009. July 2009 para 5.9 and 5.10. p. 117

[63] 2009 estimated cooking usage.
Oven usage : Electric : 64 % (3.8 TWh) ; Gas – 36% (2.7 TWh).
Hob usage : Electric – 45 % (3.2 TWh) ; Gas – 55 % (4.8 TWh)

[64] 4.8% of final end-use energy consumption in households is electric space heating and 12.4% of hot-water is electrically heated. A large proportion of both is likely to be off-peak. In 2008, 31 % of electricity consumed in the domestic sector (~36 TWh) was reported as being purchased under some form of off-peak pricing structure. Digest of UK Energy Statistics. July 2009. Chapter 5 on Electricity. P.120 para 5.25 and Table 5.3.

In 2007, 1 million households had electric storage heating as 'central heating' and 856,000 as electric 'other' (presume some new homes and high-rise). Energy Consumption in UK. BERR 2008 and DECC. July 2009 update. Tables 3.7 & 3.14. On numbers of multi-rate household meters in GB, Energy Billing and Metering. Changing Customer Behaviour. An Energy Review Consultation. BERR. November 2006 (page 22) states that there are 3.3 million multi-tariff domestic electricity meters (ie with a two-rate or higher capability (ie Profile 2 meters) – but this does not necessarily mean that 3 million customers are presently on off-peak tariffs. The Radio Teleswitch website indicates that there are believed to be around 3 million meters equipped with tele-switch (www.radioteleswitch.org.uk) – but some older multi-rate meters will not necessarily be tele-switched. And some teleswitch equipped meters will not be used at multi-rate tariffs.

[65] DUKES – July 2009. p.117 and p.134

[66] See Chart in Annex 3 for expected impact of implementing by 2020 known and likely product standards on major electrical appliance-load (including measures covered by the EU Framework Directive for the Eco-Design of Energy Using Products). In very broad terms, improved product standards for lighting, consumer electronics and ICT can be expected to bring electrical consumption for these appliances back down towards 2006 consumption levels by 2020. See in particular, 'Saving Energy Through Better Products and Appliances – a consultation on analysis, aims and indicative standards for energy efficient products 2009-2030'. DEFRA. December 2009 and Policy Analysis and Projections 2006/08. Market Transformation Programme. March 2008.

[67]Op cit : DEFRA 2009 & MTP 2008. Also, for the future, based on the Element Energy assessment, CCC identify as a key indicator of progress towards UK 2022 carbon budgets an increase in stock penetration of A+ rated Wet Appliances of 82% by 2022, and A++ Cold Appliances of 45% by 2022. – CCC- October 2009. p.151.

[68] CCC. October 2009. p.220.

[69] Renewable Heat Technologies for Carbon Abatement: Characteristics and Potential. NERA, Entec & Element Energy. Report for the Committee on Climate Change. July 2009

[70] Range : assumed low-end range from 500,000 by 2022 - to a stretch estimate of 6 million (judged unlikely).

[71] NERA assume 3 kW per unit – giving 3 GW peak for 1 million units – equivalent to 4% of peak grid capacity. (Ie a small number of ASHPs could quickly have a very significant effect on the network – illustrated

by recent local practical experience in the North East where a housing project installing heat pumps – Jon Bird CE Electric. Market Force / ASI conference. December 2009). NERA go on to speculate that if half of the UK's 26 million homes eventually had ASHPs in their present form, without a storage capability, this could add a peak of 40 GW – ie 50% of total grid capacityu. P.28

[72] BEAMA has raised a concern that present SAP (Standard Assessment Procedure) rating and Part L of the Building Regulations for new homes, may inhibit installation of new electric heating, including heat pumps because of the way the carbon compliance rating for a new home is calculated under SAP, and which BEAMA believes fails to take enough account of the extent of electricity decarbonisation int the long-term.

[73] Report for DECC on Dynamic Demand. November 2008. Also on Load Response - Mackay. Sustainable Energy Without the Hot Air. 2009 – who estimates that each refrigerator on average 18 watts, say 30 million fridges. To switch off all domestic refrigeration would therefore be the equivalent of 0.54 GW – ie >1% of national total demand.

[74] RLtec and Npower initial trial on 300 household fridges announced December 2008. Similarly, in California, Southern California Edison announced a program for 300,000 participating air-conditioners to participate in aggregated services to serve as electric power reserves to be bid into the wholesale electricity market. Metering International. 3 June 2009.

[75] DECC. Impact assessment of a GB-wide smart meter roll-out for the domestic sector. December 2009. p.44 Option 2.

[76] Project Discovery Energy Market Scenarios, Ref 122/09; Ofgem; October 2009.

[77] Decarbonising the GB power sector: evaluating investment pathways, generation patterns and emissions through to 2030; Redpoint Energy; September 2009.

[78] Market outlook to 2022 for battery electric vehicles and plug-in hybrid electric vehicles; AEA;June 2009 and Strategies for the uptake of electric vehicles and associated infrastructure implications; Element Energy; October 2009.

[79] Renewable Heat Technologies for Carbon Abatement: Characteristics and Potential; NERA, Entec & Element Energy; July 2009

[80] Slides from Ian Povey, Electricity North West Ltd (ENW). IEA DSM workshop. 21 October 2009. Chester. www.ieadsm.org

[81] Valuation of energy use and greenhouse gas emissions for appraisal and evaluation; HM Treasury & DECC; January 2010.

[82] Smart Metering Implementation Programme. Second Briefing Event. 1 February 2010.

ANNEX I

SUMMARY CHARTS TO INDICATE WHERE ECONOMIC POTENTIAL MAY SIT IN THE ELECTRICITY AND GAS SUPPLY CHAINS FROM HOUSEHOLD PEAK / LOAD FOLLOWING AND DEMAND REDUCTION TARIFFS.

1. Household Electricity Peak Demand / Load Control / Load Following Tariffs – Potential Cost Savings
Energy (generation) costs
Represent 50-60% of the bill so this is where most potential lies for cost reductions. Some peak / load control benefits could accrue pre-2020 although they would be more substantial post-2020 . The main long-run benefit will come from deferred or avoided peak plant investment and will be a particular benefit to integrated generators/suppliers (plus some limited fuel-saving). Non vertically integrated generators have less to gain and they may actually lose – as they may not be able to sell all their output.
System Operation costs
Improvements in overall system balancing costs if household peak-response can offer additional / competing resource over and above existing services available for balancing. (BSUoS is a small proportion of electricity end-price – but balancing costs (especially locational) expected to increase into 2020's due to increased nuclear (inflexible) and wind (intermittent), so reducing balancing costs will become increasingly important in the 2020's and providing demand-side flexibility likely to have a high premium. Lower imbalance costs could feed through into lower imbalance charges to integrated and non-integrated generators and suppliers who impose these lower costs.
Network costs (T&D)
Distribution represents around 15% of total end-price of electricity (~£60 to £70 pa on an average bill) and Transmission less than 3%, so the overall scope for cost reductions is perhaps less[83]. Distribution networks are built to cope with expected peak demand and as of today, generally, DNOs can adequately meet the peaks occurring on their networks. Peak-demand reduction could reduce losses (December 2009 Meter Impact Assessment value - £388m – split 50:50 customer & networks), but beyond this may have relatively modest economic or operational value to the networks as at today. Potential network peak-cost savings are most likely post-2020, if responsive electricity demand grows significantly (on-peak heating, vehicles). The savings would be mainly deferred / avoided costs of network reinforcement / new investment. Post-2020, additional (and perhaps significant) savings available from loss reduction. Networks could in time pass through reduced network charges to suppliers who are able to guarantee a given and sustained level of household peak reduction.
Environmental charges
Reduced electricity demand at peaks will only reduce environmental costs if the demand is not shifted to other times of the day. The main scope to reduce environmental costs is in respect of the renewable electricity target and RO-related costs. (see under overall electricity demand reduction below).
Customers
Suppliers could pass through some of their savings of avoided generation, network and system operation costs, in peak reduction tariffs, to those customers who help reduce these costs on their behalf (subject to improved profiles / settlement arrangements for small customers). Customers most likely to see savings on their electricity bills are those with flexible electrical load to shift and / or anyway use most electricity off-peak (however off-peak defined)[84]. Available bill savings may be modest now – but potential cost-savings from peak likely to increase in the 2020's. Experience elsewhere (Northern Ireland, Australia, and US) suggests that a large proportion of customers are able to obtain energy bill savings from peak tariffs[85].

2. Household Electricity Overall Demand Reduction Tariffs – Potential Cost Savings
Energy (generation) costs
Most of the potential cost savings are in this area – either from avoided short-run operational costs - or from long-run avoided or deferred capital costs of new generation. Integrated players will benefit. Non-integrated players may not benefit unless they can take advantage of operational savings and thereby reduce their imbalance exposure, effectively through demand-side hedging. Importantly, an electricity tariff which incentivised less electricity use overall (eg an electricity Increasing Block Tariff) **– without a time-of-use message – would give no incentive to avoid peak time usage. Therefore, customers could use less electricity overall but not reduce (or could even add) to higher costs of meeting system peaks. So cost savings may be modest.**
System Operation costs
Potential cost-savings in system balancing if less electricity demand overall enables SO to contract for lower levels of response, reserve etc. Becomes more material in 2020s if electricity demand growing significantly and system increasingly wind-dominated. But overall demand reduction does not necessarily reduce high-cost peaks – and so issues will be same as for generation (see above).
Network costs (T&D)
Significant reduction in network costs unlikely from reducing overall throughput of units - because network costs are driven by peak requirements.
Environmental charges
Reduced electricity demand will potentially make it easier for suppliers to meet the renewable electricity target and thereby save on RO-related costs. Reduced demand could also benefit generators as they may need to purchase fewer EU ETS permits.
Customers
Suppliers could pass through some of their savings on generation, environmental and system operation costs to those customers who help to reduce these costs. Pre-2020, scope for cost reductions (and hence benefits that could pass through to customers) would seem greater for overall electricity demand reduction than for electricity peak demand reduction – but this could reverse in the 2020's when peak costs are expected to be considerably higher than now. Customers would see savings on their electricity bills if they reduce their electricity-use over a fixed time-period (say, annual)[86] .

3. Household Gas Peak Demand Reduction Tariffs – Potential Cost Savings
Energy costs
Household gas-use is highly temperature dependent and has strong peak characteristics (time-of-day, day-of-the-week, winter, seasonal shoulders). Reducing peak gas demand would enable lower gas purchasing costs and storage-related costs for suppliers and shippers (a main benefit). However, retail peak–prices for gas (especially *within day*) would not reflect underlying costs as presently reflected in gas market commercial arrangements[87] .
System Operation costs
Possibly some cost efficiencies in improvements in balancing the gas system at peak – eg highly seasonal aspects of demand, pipeline pressure and gas quality. But present commercial arrangements are based on a daily gas balance.
Gas Network (T&D costs)
Very limited cost savings available to gas networks from peak demand reduction – gas networks are already sized to meet peaks - and household gas demand not expected to grow significantly (and indeed may decline).
Environmental charges
No benefit likely available from reduced environmental charges
Customers
Suppliers could see some cost reductions that they could pass through to customers in peak shifting gas tariffs (eg off-peak rates for weekends, middle-of-the-day etc). This could reduce bills for some customers– but households with inflexible or large peak-time gas-use could suffer. Also, peak gas tariffs could trigger switching to electric heaters / water heating. In addition, peak gas tariffs may in practice reduce demand overall, because some gas used for heating may not shift to another time of day – so customers could see bill savings from this effect.

4. Household Gas Demand Reduction Tariffs – Potential Cost Savings
Energy costs
Reducing overall gas use could : reduce gas purchase costs for suppliers and shippers. Unlike for electricity, absence of within-day time-of-use message does not appear to risk introducing short-term additional costs. However, over time, a block gas-tariff could perhaps serve to increase the peakiness of household gas-use (and associated costs) as measures to reduce unnecessary boiler-use (eg adjust boiler clocks, thermostats, insulation) begin to take effect[88].
System Operation costs
Potential cost-savings in improved system balancing if less gas household demand over the year enables reduced storage or other improvements in balancing-related costs.
Gas Network (T&D costs)
Cost savings unlikely (as for peak demand gas tariffs).
Environmental charges
Reduced gas use overall will contribute to carbon reduction (see section 3) and should make it easier to meet the renewable heat target which will reduce costs to gas suppliers (ie reduce Renerwable Heat Incentive liability).
Customers
Suppliers could see cost reductions that they could pass through to customers. Customers who respond to incentives to reduce gas use demand should therefore see lower bills - (but potential concerns for underheating amongst low income and vulnerable households).

ANNEX 2 - Estimated UK Domestic Electrical Appliance End-Use 2009 and 2020 (minus heating & hot water)

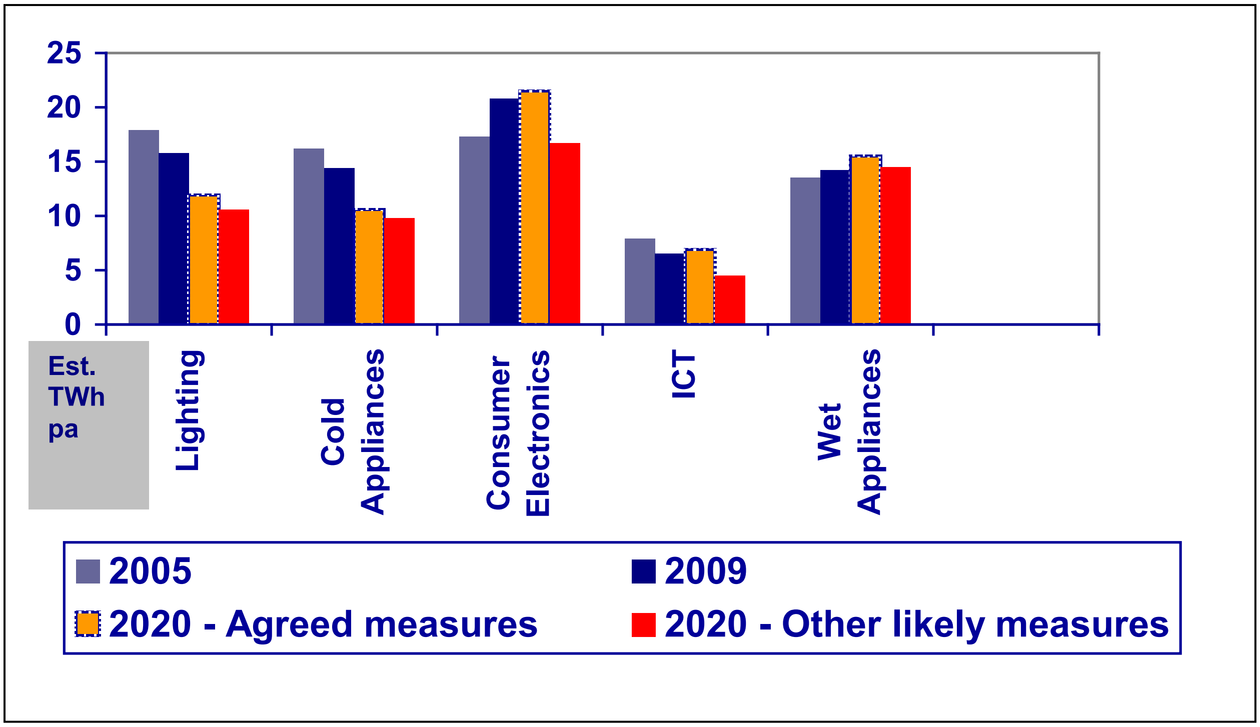
Estimated UK Domestic Electrical Appliance End-Use 2009 and 2020 *(minus heating & hot water)*				
Domestic Electrical Appliance Use (estimates from MTP Stock Model)	**% age of all domestic electrical appliance load 2009** (estimated)	**TWh pa in 2009** (estimated**)**	**TWh pa in 2020** (estimated)*	
			Reference Scenario *(assumes all policy measures agreed before July 2009)*	**Policy Scenario** *(assumes additional potential from eg standards, info, labels))*
Domestic Wet Appliances **Dishwashers 3.2 TWh** *ownership – 28.5%* assu*med av. use - 248x p* **Washing Machines 4.3 TWh** *ownership 80% - assumed av. use - 274x pa* **Washer Driers 2.3 TWh** *ownership 15%* **Tumble Driers 4.3 TWh** *ownership 39%* *assumed av. use - 148x pa*	17 %	14.2	15.5	14.5
Cold Appliances Freezers / Refrigerators	17%	14.4	10.6	9.8
Cooking **Electric Ovens 3.8 TWh** *ownership 64%* **Electric Hobs 3.2 TWh** *ownership 55%* **Microwaves – 2.4 TWh** o*wnership 85%*	11%	9.4		
Kettles – *ownership 97%*	5%	4.2		
All Consumer Electronics TVs 8.3 TWh Power Supply Units 5 Set Top Boxes 3.6 Videos DVDs 3.1 Games Consoles 0.6	24%	20.8	21.5	16.7
Lighting	19%	15.8	11.9	10.6
PCs / Domestic ICT PCs 3.9 Laptops 0.7 Monitors 1.5 Imaging 0.4 (Multi Functional Devices)	7%	6.5	6.9	4.5
TOTAL – Estimated UK Domestic Electrical Appliance End-Use Minus heating and hot water. 2009	**100%**	**85.3 TWh pa**		

*__Note on Scenarios__ _ Implementing measures under the Energy-using Products Directive agreed before July 2009 are included in **2020 Reference** scenario (eg External Power Supply Units, Simple Set Top Boxes, Non-directional Domestic Lighting, Cold Appliances, TVs). Other measures agreed or likely to be agreed ***post July 2009*** are included in the **2020 Policy Scenario**

Sources – Saving Energy Through Better Products and Appliances. A consultation on analysis, aims and indicative standards for energy efficient products 2009 – 2030. DEFRA. December 2009. Policy Analysis and Projection 2006/08. Market Transformation Programme. March 2008 – *www.mtprog.com*

ANNEX 3

Chart – Estimated Household Electrical Appliance Load in 2020 - Potential impact of agreed and likely product measures



Sources : Inputs from : Saving Energy Through Better Products and Appliances. A consultation on analysis, aims and indicative standards for energy efficient products 2009 – 2030. DEFRA. December 2009. Policy Analysis and Projection 2006/08 Market Transformation Programme. March 2008 & earlier 2006 study – *www.mtprog.com*

ANNEX 4 – Brattle Modelling

The Brattle Group have undertaken some high level modelling based on the findings of this report – the main findings of this are included in Section 6.5 of the report. This Annex provides the detailed results of that modelling and the assumptions used.

Potential available economic and carbon savings from household demand response to 2030.

Calculations of consumer and carbon savings

1. General assumptions

There were a number of assumptions that we applied to all our cases. First, we used a discount rate of 3.5% to calculate net present values, in line with the assumptions made in the original Mott McDonald calculations for DECC. Second, we assumed that the numbers of electricity consumers would increase linearly over time in line with the projections produced by DEFRA in October 2009 in its consultation on "Saving Energy Through Better Products and Appliances".[1] We did not assume any corresponding increase in gas consumers. Third, we adopted the assumptions on smart meter roll out produced by Baringa Partners for the central communications model.[2]

2. Electricity demand reductions

(a) Consumer benefits

The savings for consumers have been calculated using the breakdown of electricity consumer bills provided by Ofgem in its September 2009 Project Discovery scenarios consultation. This broke down bills into: wholesale electricity costs, ROC + CC subsidies, energy efficiency + smart meters, transmission and distribution costs, BSUoS and gross margins.[3] To calculate savings per consumer, we

- applied DECC's demand reduction assumptions (2.8% base case, 1.5% and 4% for sensitivities) to the wholesale costs and gross margins;
- assumed that 90% of the ROC +CC subsidies came from ROC costs and applied DECC's demand reduction assumptions to this proportion of these costs;
- we did not reduce energy efficiency + smart meter costs or (implicitly) CCS subsidies on the grounds that these were "fixed costs" so that if demand went down the unit charge would rise proportionately.
- estimated what a 2.7% reduction in demand might mean for transmission and distribution costs, assuming that the savings from reducing peak demand would be

[1] See page 56.
[2] "Smart Meter Roll Out: Market Model Definition and Evaluation Project", April 2009, Table 3. We assume that "year 1" corresponds to 2012.
[3] See page 94.

around 62 £/kVA/yr based on a worked example by Ian Povey of NorthWest Networks. In July 2009, IHS Global Insight estimated that domestic peak demand is around 17 GW[4] so a 2.8% reduction equates to lowering peak demand by 0.5 GW or £29.5 million. Spreading this over all consumers yields a saving of £1.14 per consumer, which is 1.3% of the 2010 T&D costs. We used this percentage for all the cases we explored involving a 2.8% reduction in demand. For the DECC sensitivities, we adjusted the calculation appropriately;

- assumed that these savings were only available to consumers with smart meters and that the 20% of consumers who DECC assumes will respond to TOU tariffs do not also make overall demand reductions i.e. only 80% of consumers with smart meters are included in our calculations.

Note that Ofgem assumes that the average demand of customers decreases over time from 3,300 kWh due to energy efficiency measures in some unspecified manner. Since we simply apply DECC's demand reduction assumption to the estimates of consumer bills, this may mean that we over-estimate the effects of smart meters since the level of consumer bills to which we apply a percentage reduction will be lower than they should be if the reduction is meant to capture the effect of smart meters.

The Ofgem scenarios only extend to 2020, beyond this we generally assume that the various cost components will change at the same rate that Ofgem assumes they will vary between 2015 and 2020. However, this approach would have given rise to extremely high wholesale electricity prices and we moderated this effect by applying the year on year changes in wholesale prices modelled by Redpoint Energy for the CCC. We used Redpoint's "environmentally favourable conditions" scenario for the Green Transition and green stimulus scenarios and its "high perception of risk, no foresight on carbon prices" scenario for the

(b)Carbon savings

In line with the DECC guidelines on valuing greenhouse gas emissions[5], the carbon savings are estimated on the basis of the marginal CO2 intensity of electricity. However, we have not simply used the DECC assumption on marginal CO2 intensity (0.430 kg/kWh) but have explored other assumptions based on average CO2 intensities reported by Redpoint Energy[6] and AEA[7].

Redpoint provided Element Energy with information on the marginal and average CO2 intensity of electricity in 2030 by time of day, which suggested that the marginal intensity was approximately 2.5 times as high as average emissions[8]. For some of our cases, we assumed that this ratio was applicable in all years, whilst for others we adopted the DECC assumption.

[4] "Demand Side Market Participation Report" for DECC, Table 9.
[5] "Valuation of energy use and greenhouse gas emissions for appraisal and evaluation", HM Treasury and DECC, January 2010.
[6] "Decarbonising the GB power sector: evaluating investment pathways, generation patterns and emissions through to 2030", September 2030.
[7] From Figure 4.1, "Meeting Carbon Budgets – the need for a step change", CCC, October 2009.
[8] See Figure 30, "Strategies for the uptake of electric vehicles and associated infrastructure implications", October 2009. From these, Element Energy calculated electric vehicles emissions of 30 g/km based on average emissions, 65 g/km based effectively on off-peak marginal emissions and 80 g/km based on peak marginal emissions. From these figures and the fact that Redpoint found average emissions were essentially constant across the day, we deduced average to marginal factors for off-peak and peak electricity of 2.83 and 2.17, and weighting these values to account for the percentage of overall demand consumed in peak and off-peak periods (54% and 46%), we arrived at an average figure of 2.51.

To translate the "savings" in CO_2 emissions into monetary terms[9], we used CO_2 prices consistent with the consumer savings that we calculated i.e. we used the same Ofgem scenarios for both consumer bills and CO_2 prices.

3. Peak shifting and peak demand reductions

(a) Consumer benefits

For peak shifting, we assume that there is no net reduction in a consumer's demand. The benefits therefore come from switching consumption from peak to off-peak periods. Consequently, the only impacts that we take into account are changes in wholesale electricity costs and changes in transmission and distribution costs.

Based on an analysis of year-ahead forward prices over the past three years, we assume that peak prices are approximately 1.24 times baseload prices and, hence, that off-peak prices are approximately 0.75 baseload prices. Using these assumptions and an analysis of the data on domestic demand profiles provided by IHS Global Insight[10] which suggests that consumption during peak periods accounts for 54% of overall consumption, it is possible to calculate what the change in wholesale costs should be from peak shifting.[11] For transmission and distribution charges, we make essentially the same assumption as for electricity demand reductions, except that we assume that only 90% of the reductions are available from peak shifting – on the grounds that broadly speaking these charges are 90% capacity related and 10% commodity related. Note that we do not attempt to adjust prices for the effect of changes in domestic demand patterns.

We use a similar approach to calculate the benefits from peak reductions, except that in this case there is no offsetting increase in off-peak demand. Consequently, we also include allowances for reductions in ROC costs and gross margins, using the same methodology as described for electricity demand reductions.

In line with DECC's assumptions, we assume that 20% of consumers respond to TOU tariffs either by peak shifting or reducing their peak demand. The DECC Impact Assessments (IA) do not make it clear what split between peak shifting and peak reduction has been assumed. For most cases, we assume a 50% split between peak shifting and peak reduction but explore the impact of 100% peak shifting (very little impact) and 100% peak reduction (much larger impact). Our base case assumption is that both responses result in a 2.8% decrease in peak demand. This is in line with the assumption in the May 2009 DECC IA (see page 34). However, the December 2009 IA suggests that DECC may have reverted to assuming a 5% peak effect[12] (which was its original April 2008 assumption) despite the fact that this is not listed as a change in base assumptions.

---

[9] As DECC acknowledges, carbon savings in the electricity market do not lead to an overall net reduction in global emissions since the emissions will be transferred elsewhere within the ETS.

[10] Demand Side Market Participation Report" for DECC, Figure 4.

[11] $(f_p - f_{op}) \times r \times 0.54 \times D / (f_{op} \times 0.46 \times D + 0.54 \times f_p \times D)$ where f_p is the ratio between peak and baseload prices, f_{op} is the ratio between off-peak and baseload prices, r is the percentage reduction in peak demand and D is total consumer demand.

[12] See, for example, page 54.

Our methodology is very different to that adopted by DECC, which is based on avoided investment costs. Whilst we understand the rationale for this approach, the calculations rely on assumptions regarding when investment can be delayed and we did not have sufficient information available to be able to attempt such a calculation.

(b)Carbon savings
Our approach was the same as that outlined for electricity demand reductions, except that we took into account the difference between peak and off-peak marginal CO2 intensity. Thus for peak shifting the savings only relate to this difference multiplied by the volume of demand that is shifted, whereas for peak reduction the saving is the full reduction in peak demand.

4. Gas demand reductions

(a) Consumer benefits
The savings for consumers have been calculated using the breakdown of gas consumer bills provided by Ofgem in its September 2009 Project Discovery scenarios consultation. This broke down bills into: wholesale gas costs, renewable heat incentive (RHI), energy efficiency + smart meters, transmission and distribution costs, and gross margins.[13] To calculate savings per consumer, we estimate what the average overall reduction in gas demand due to smart meters would be from DECC's assumptions that credit customers would reduce demand by 2% and pre-payment customers by 0.5%. Given that DECC estimates that 90% of customers are credit customers[14], this means that on average there is a reduction of 1.86%. We applied this reduction to both wholesale gas costs and gross margins but made no other reductions. On the assumption that overall gas demand is likely to go down rather than up, we made no reductions to transmission and distribution charges nor did we adjust RHI or energy efficiency + smart meter costs: as in the case of electricity demand reductions we assumed that these were fixed costs.

Ofgem's customer bill projections were based on an average consumption of 20,500 kWh in 2009 reducing in an unspecified way due to energy efficiency and renewable heat technologies. Since we simply applied DECC's demand reduction assumption to the estimates of consumer bills, this may mean that we over-estimate the effects of smart meters since the level of consumer bills to which we apply a percentage reduction will be lower than they should be if the reduction is meant to capture the effect of smart meters.

We also explored the impact of the sensitivities outlined by DECC, namely 3%/1% and 1%/0.3% credit/pre-pay reductions as well as the effect of the four different scenarios produced by Ofgem. The Ofgem scenarios only extend to 2020, beyond this we assume that the various cost components will change at the same rate that Ofgem assumes they will vary between 2015 and 2020.

(a) Carbon savings
We adopted DECC's assumptions regarding the marginal CO2 intensity of gas of 0.185 kg/kWh and its non-traded carbon price assumptions. We explored the impact of changing between its high, central and low projections.

[13] See page 83.
[14] Footnote 29, page 34 of the December 2009 IA.

5. Electric vehicles

(a) Consumer benefits

We have assumed that smart meters would result in consumers charging their cars at night, thus lowering their costs, and hence encouraging a more rapid uptake of electric vehicles. As far as we are aware, the DECC IA does not take into account the impact of an increase in electric vehicles.

In considering how the number of electric vehicles might change with smart meters, we have switched between the scenarios created by AEA for the CCC – our base assumption is a switch from scenario 2 to scenario 4.[15] We further assume that each car is used for 40 km/day and requires 8 kWh of charging, based on the analysis carried out by Element Energy for the CCC.[16]. We calculate the electricity consumption associated with electric vehicles without smart meters on the basis that this involves charging during peak hours and estimate peak electricity prices from multiplying our historic analysis of peak:baseload price factors with Ofgem's projections of wholesale electric costs under its four scenarios. For the smart meter case, we assume more electric vehicles and off-peak charging (again estimating off-peak prices from a combination of our historic analysis of off-peak to baseload prices and Ofgem scenarios). We assume that the increase in electricity consumption would also be reflected in higher gross margins but do not adjust any other elements of consumers' bills. This analysis enables us to estimate the impact of smart meters on the additional costs in consumer electricity bills associated with electric vehicles.

We then deducted the petrol costs that consumers avoid from having electric vehicles. For consistency with our electricity cost scenarios, we rely on Ofgem's crude oil price scenarios. We did this by comparing 2009 average petrol prices excluding taxes with 2009 crude oil prices and assume that the ratio between the two prices remains constant over time. We can then estimate petrol prices using Ofgem's forecasts of crude oil prices (These projections end in 2025, beyond then we apply the same rate or change in prices as that assumed by Ofgem between 2020 and 2025). To these untaxed prices, we then add excise tax (assumed to increase at 1% above inflation) and VAT. Finally, we estimated average petrol consumption levels from Element Energy's estimate that average fleet emissions will be 120 g/km in 2020 and 100 g/km in 2030 and linearly interpolating to find values for other years. Knowing the carbon intensity of petrol, we can then determine how many litres of petrol consumers have to purchase.

(b) Carbon savings

We have estimated the carbon savings due to smart meters from the difference in carbon savings from electric vehicles with and without smart meters. Without smart meters, electric vehicles are assumed to be charged during peak hours, so we calculate emissions using our estimate of peak marginal CO_2 intensity (see footnote 8 above for details). We then compared these emissions to those associated with petrol cars using the assumptions on average emissions outlined above. With smart meters, we assume off-peak charging and hence electricity emissions are calculated using off-peak marginal CO_2 intensities.

---

[15] See tables 6.17 to 6.20, "Market outlook to 2022 for battery electric vehicles and plug-in hybrid electric vehicles", June 2009. Beyond 2022, we assume penetration rates increase at the same rate as between 2018 and 2022.

[16] Section 5, "Strategies for the uptake of electric vehicles and associated infrastructure implications", October 2009.

Despite the fact that additional electric vehicle usage generates global emissions savings, we have calculated the monetary value of the savings on the basis of the traded price of carbon i.e. using Ofgem's carbon price scenarios. This is a conservative assumption in that the non-traded carbon price assumed by DECC is significantly higher than the traded carbon price. We adopted this assumption on the basis that the increase in electricity consumption generated CO2 costs dependent on the traded price of carbon.

6. Oil heating to heat pumps

(a) Consumer benefits

We have assumed that smart meters would result in more consumers switching away from oil heating to heat pumps. We have concentrated on this form of switching because it is not obvious that switching from gas heating to heat pumps would deliver any environmental benefits, or be cost effective.

We have relied on air-source heat pump uptake scenarios produced by NERA, Entec and Element Energy for the CCC[17]. Our base assumption is that impact of smart meters is generally to move the uptake of heat pumps from the Low to the Central scenario. However, depending on the wholesale electricity price scenario being studied, the running costs associated with heat pumps can be higher than those associated with oil. In these years, we assume that no further switching occurs until there is once again a running cost saving. At that point, the switching rates are assumed to move on by one year from the year where switching stopped.[18]

In line with the assumptions in this report, we assume that customers who switch to heat pumps consume 8000 kWh of energy, that oil heating has an efficiency of 90% whilst heat pumps are 300% efficient. We took the total unit prices paid by consumers under Ofgem's scenarios and calculated the costs associated with the increased electricity consumption. This may under-estimate the actual costs because heat pumps would increase electricity demand across the day (there is presently relatively little storage associated with heat pumps) and so might well increase wholesale prices.

Consumers switching to heat pumps will avoid the oil costs they would otherwise have paid. We estimated the price of heating oil in exactly the same way as we estimated petrol prices i.e. by deriving a ratio between 2009 heating oil prices (excluding taxes) and crude prices and assuming that this ratio is maintained in the future.

(b) Carbon savings

We have estimated the carbon savings due to smart meters from the difference in carbon savings from switching to heat pumps with and without smart meters. We assume that the marginal intensity of oil is 0.245 kg/kWh and use our estimates of the overall marginal intensity of

[17] "Renewable Heat technologies for Carbon Abatement: Characteristics and Potential", July 2009.

[18] For example, suppose that heat pump running costs were higher than oil costs from 2019 to 2022, in 2023 we would calculate the number of customers changing from the NERA scenarios for 2019.

electricity as it varies from Ofgem scenario to scenario. As for electric vehicles, we used traded carbon prices to calculate the monetary value of the carbon savings.

Results

The following tables show the results of the various cases that we examined, which we condensed into a set of plausible ranges for the main body of the report.

---

[83] IHS Global Insight – Demand Side Participation Report. July 2009 – seems to concur with this view. Para 6.1 says ''The price differential between peak and off-peak tariffs also reflects how distribution and transmission charges are applied…investment in the distribution and transmission infrastructure is not assumed to be significantly reduced by increased levels of DSM'.
Similarly, Frontier Economics 'The Role of Future Energy Networks' Report for Ofgem. September 2009 p.38 and p.42.

[84] DECC Consultation Impact Assessment of Smart Metering Roll-Out. December 2009. (Central Comms, Central Estimate). Assumes (mid-range) a 20% take-up of a ToU tariff, and assumes a 3 % overall electricity bill reduction and a 5 % peak-use reduction (p.25)

[85] For example : Freeman Sullivan and Co. 2008 Load Impact Evaluation for Pacific Gas and Electric Company's Smart Rate, Smart AC and Residential ToU Programs. May 2009 ; Chris King E-Meter. PowerCents Trial. Barcelona. October 2009; Smart Meter Consumer Impact. Initial Analysis. A Report to the Ministerial Council on Energy Standing Committee of Officials. Energy Marketing Consulting associates (EMCa). Analysis for Integral Energy and Energy Australia. April 2009.

[86] DECC Smart Meter Impact Assessment – assumes 2.8% electricity saving from improved feedback on usage.

[87] Electricity has a half-hourly pricing structure which can to some extent reflect the underlying costs of electricity system balancing. Hence, electricity prices which change throughout a day could, to some degree, reflect underlying costs. Although household gas use has peak-related characteristics, (and therefore presumably some peak-related costs) these are not presently reflected in the commercial gas market arrangements, which provide for a single daily balancing price, because short term gas storage is available within-day (line-pack, safety monitors).

[88] DECC Smart Meter Impact Assessment – assumes 2% gas saving from improved feedback (0.5% from gas pre-pay).

													Customer beneifts, NPV 2010 money, £ million							
Gas reduction		Elec reduction											2010-2020				2021-2030			
Credit	PPM	Demand	ToU	Price scenario	Carbon scenario	Electric heating Base	SM	Pk shift as % TOU take up	Carbon intensity	Elec redn assumption	Electric vehicle Base	SM	Electricity demand	Peak shift	Fuel switching	Gas saving	Electricity demand	Peak shift	Fuel switching	Gas saving
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	877	73	197	1,012	1,519	131	3,276	1,559
2%	0.5%	2.8%	2.8%	Green stimulus	Green stimulus/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	715	62	194	876	1,313	117	3,896	1,374
2%	0.5%	2.8%	2.8%	Dash for energy	Dash for energy/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	1,169	97	193	1,489	1,783	151	3,456	1,083
2%	0.5%	2.8%	2.8%	Slow growth	Slow growth/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	989	82	146	1,046	1,892	160	2,584	2,068
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	AEA	Marginal	AEA 2	AEA 4	877	73	197	1,012	1,519	131	3,276	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	HPR	Marginal	AEA 2	AEA 4	877	73	197	1,012	1,519	131	3,276	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	DECC	Marginal	AEA 2	AEA 4	877	73	197	1,012	1,519	131	3,276	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	DECC	DECC Margi	AEA 2	AEA 4	877	73	197	1,012	1,519	131	3,276	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Central	High	50%	EFC	Marginal	AEA 2	AEA 4	877	73	196	1,012	1,519	131	3,265	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	877	73	206	1,012	1,519	131	3,182	1,559
2%	0.5%	2.8%	2.8%	Green stimulus	Green stimulus/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	715	62	198	876	1,313	117	3,930	1,374
2%	0.5%	2.8%	2.8%	Dash for energy	Dash for energy/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	1,169	97	203	1,489	1,783	151	3,607	1,083
2%	0.5%	2.8%	2.8%	Slow growth	Slow growth/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	989	82	146	1,046	1,892	160	2,584	2,068
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	AEA 2	877	73	138	1,012	1,519	131	1,090	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	AEA 3	877	73	409	1,012	1,519	131	5,389	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	AEA 4	877	73	324	1,012	1,519	131	4,449	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	100%	EFC	Marginal	AEA 2	AEA 4	877	0	197	1,012	1,519	0	3,276	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	0%	EFC	Marginal	AEA 2	AEA 4	877	114	197	1,012	1,519	217	3,276	1,559
3%	1.0%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	877	73	197	1,356	1,519	131	3,276	2,145
1%	0.3%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	877	73	197	677	1,519	131	3,276	990
2%	0.5%	4.0%	4.0%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	1,253	105	197	1,157	2,171	187	3,276	1,737
2%	0.5%	1.5%	1.5%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	470	39	197	854	814	70	3,276	1,366
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	DECC Margi	AEA 2	AEA 4	877	73	197	1,012	1,519	131	3,276	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Low	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	877	73	197	1,012	1,519	131	3,276	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT High	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	877	73	197	1,012	1,519	131	3,276	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	Arup mid	877	73	1,893	1,012	1,519	131	4,684	1,559
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	Arup mid	Arup high	877	73	1,858	1,012	1,519	131	9,821	1,559

													Carbon savings, million tonnes							
Gas reduction		Elec reduction											2010-2020				2021-2030			
Credit	PPM	Demand	ToU	Price scenario	Carbon scenario	Electric heating Base	SM	Pk shift as % TOU take up	Carbon intensity	Elec redn assumption	Electric vehicle Base	SM	Electricity demand	Peak shift	Fuel switching	Gas saving	Electricity demand	Peak shift	Fuel switching	Gas saving
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.2	8.3	12.2	1.1	13.3	15.7
2%	0.5%	2.8%	2.8%	Green stimulus	Green stimulus/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.2	8.3	12.2	1.1	15.7	15.7
2%	0.5%	2.8%	2.8%	Dash for energy	Dash for energy/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.2	8.3	12.2	1.1	15.2	15.7
2%	0.5%	2.8%	2.8%	Slow growth	Slow growth/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	0.2	8.3	12.2	1.1	10.8	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	AEA	Marginal	AEA 2	AEA 4	15.1	1.4	-1.1	8.3	13.4	1.3	12.7	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	HPR	Marginal	AEA 2	AEA 4	11.5	1.1	-0.2	8.3	18.0	1.7	2.5	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	DECC	Marginal	AEA 2	AEA 4	11.7	1.1	-0.2	8.3	15.5	1.5	6.2	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	DECC	DECC Marginal	AEA 2	AEA 4	5.1	0.5	1.3	8.3	10.5	1.0	13.3	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Central	High	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.1	8.3	12.2	1.1	13.7	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.5	8.3	12.2	1.1	16.3	15.7
2%	0.5%	2.8%	2.8%	Green stimulus	Green stimulus/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.5	8.3	12.2	1.1	21.6	15.7
2%	0.5%	2.8%	2.8%	Dash for energy	Dash for energy/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.4	8.3	12.2	1.1	20.5	15.7
2%	0.5%	2.8%	2.8%	Slow growth	Slow growth/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	0.2	8.3	12.2	1.1	10.8	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	AEA 2	11.4	1.1	-0.4	8.3	12.2	1.1	6.9	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	AEA 3	11.4	1.1	-0.7	8.3	12.2	1.1	15.4	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	AEA 4	11.4	1.1	-0.6	8.3	12.2	1.1	13.7	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	100%	EFC	Marginal	AEA 2	AEA 4	11.4	0.4	-0.2	8.3	12.2	0.4	13.3	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	0%	EFC	Marginal	AEA 2	AEA 4	11.4	1.7	-0.2	8.3	12.2	1.8	13.3	15.7
3%	1.0%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.2	12.6	12.2	1.1	13.3	23.7
1%	0.3%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.2	4.2	12.2	1.1	13.3	7.9
2%	0.5%	4.0%	4.0%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	16.3	1.5	-0.2	8.3	17.4	1.6	13.3	15.7
2%	0.5%	1.5%	1.5%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	6.1	0.6	-0.2	8.3	6.5	0.6	13.3	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	DECC Marginal	AEA 2	AEA 4	5.1	0.5	1.3	8.3	10.5	1.0	13.3	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Low	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.2	8.3	12.2	1.1	13.3	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT High	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	11.4	1.1	-0.2	8.3	12.2	1.1	13.3	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	Arup mid	11.4	1.1	-2.6	8.3	12.2	1.1	12.0	15.7
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	Arup mid	Arup high	11.4	1.1	0.9	8.3	12.2	1.1	29.7	15.7

Gas reduction: Credit	Gas reduction: PPM	Elec reduction: Demand	Elec reduction: ToU	Price scenario	Carbon scenario	Electric heating: Base	Electric heating: SM	Pk shift as % TOU take up	Carbon intensity	Elec redn assumption	Electric vehicle: Base	Electric vehicle: SM	Carbon savings, NPV 2010 money, £ million, 2010-2020: Electricity demand	2010-2020: Peak shift	2010-2020: Fuel switching	2010-2020: Gas saving	2021-2030: Electricity demand	2021-2030: Peak shift	2021-2030: Fuel switching	2021-2030: Gas saving
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	260	24	-4	359	293	27	314	582
2%	0.5%	2.8%	2.8%	Green stimulus	Green stimulus/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	221	21	-4	359	290	27	382	582
2%	0.5%	2.8%	2.8%	Dash for energy	Dash for energy/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	194	18	-3	359	201	19	237	582
2%	0.5%	2.8%	2.8%	Slow growth	Slow growth/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	142	13	2	359	173	16	161	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	AEA	Marginal	AEA 2	AEA 4	344	32	-25	359	323	30	298	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	HPR	Marginal	AEA 2	AEA 4	261	24	-5	359	432	40	59	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	DECC	Marginal	AEA 2	AEA 4	265	25	-5	359	372	35	147	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	DECC	DECC Margi	AEA 2	AEA 4	117	11	30	359	251	23	315	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Central	High	50%	EFC	Marginal	AEA 2	AEA 4	260	24	-2	359	293	27	323	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	260	24	-11	359	293	27	384	582
2%	0.5%	2.8%	2.8%	Green stimulus	Green stimulus/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	221	21	-10	359	290	27	527	582
2%	0.5%	2.8%	2.8%	Dash for energy	Dash for energy/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	194	18	-7	359	201	19	320	582
2%	0.5%	2.8%	2.8%	Slow growth	Slow growth/DECC NT Central	Low	High	50%	EFC	Marginal	AEA 2	AEA 4	142	13	2	359	173	16	161	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	AEA 2	260	24	-8	359	293	27	164	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	AEA 3	260	24	-17	359	293	27	362	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	AEA 4	260	24	-15	359	293	27	320	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	100%	EFC	Marginal	AEA 2	AEA 4	260	9	-4	359	293	10	314	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	0%	EFC	Marginal	AEA 2	AEA 4	260	39	-4	359	293	44	314	582
3%	1.0%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	260	24	-4	543	293	27	314	881
1%	0.3%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	260	24	-4	180	293	27	314	293
2%	0.5%	4.0%	4.0%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	371	35	-4	359	419	39	314	582
2%	0.5%	1.5%	1.5%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	139	13	-4	359	157	15	314	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	DECC Margi	AEA 2	AEA 4	117	11	30	359	251	23	315	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Low	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	260	24	-4	180	293	27	314	293
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT High	Low	Central	50%	EFC	Marginal	AEA 2	AEA 4	260	24	-4	539	293	27	314	875
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	AEA 1	Arup mid	260	24	-58	359	293	27	282	582
2%	0.5%	2.8%	2.8%	Green transition	Green transition/DECC NT Central	Low	Central	50%	EFC	Marginal	Arup mid	Arup high	260	24	19	359	293	27	700	582