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DECC

THE POTENTIAL FOR BEHAVIOURAL AND DEMAND-SIDE MANAGEMENT MEASURES TO SAVE ELECTRICITY, GAS AND CARBON IN THE DOMESTIC SECTOR, AND RESULTING SUPPLY-SIDE IMPLICATIONS

Department of Energy and Climate Change

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Prepared under the management of:

Caroline Doble – Project Manager

Directed, reviewed and approved by:

Mike Bullard – Project Director

Client Address:

DECC
Ergon House
Horseferry Road
London
Tina Dallman
Tel 020 7238 1227
Email Tina.Dallman@defra.gsi.gov.uk

Enviros Contact Details:

Enviros Consulting Ltd
20-23 Greville Street
London
EC1N 8SS
Caroline Doble, Consulting Group Manager
Tel 020 7421 6361
Fax 020 7430 2210
Email caroline.doble@enviros.com
Web www.enviros.com
A Carillion plc company

APPENDICES

ABBREVIATIONS

Acronym	Meaning
AMM	Advanced Meter Management
AMR	Automated Meter Reading
ASHP	Air Source Heat Pump
BEAMA	(The) British Electrotechnical and Allied Manufacturers Association
BERR	Department for Business, Enterprise and Regulatory Reform
CHP	Combined Heat and Power
CDU	Customer Display Units
CERT	Carbon Emissions Reduction Target
DA	Demonstration Action
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DIUS	Department for Innovation, Universities and Skills
DNO	Distribution Network Operators
DSM	Demand Side Management
DTI	Department for Trade and Industry
DWG	Distribution Working Group
EEAC	Energy Efficiency Audit
EDD	Electricity Display Devices
EEC	Energy Efficiency Commitment (Phase 1 and 2) – Supplier Obligations before CERT
EPC	Energy Performance Certificates
EPBD	Energy Performance of Buildings Directive
ERA	Energy Retail Associaton
ESCo	Energy Services Company
ESD	EU Directive on Energy End-Use Efficiency and Energy Services
EST	Energy Saving Trust
EDRP	Energy Demand Reduction Pilot
EU	ETS European Emissions Trading System
GPRS	General Packet Radio Service
GSHP	Ground Source Heat Pump
GSM	Global System for Mobile communications
HAN	Home Area Network
HZ	Hertz
ICT	Information Communications Technology
iDTV	Integrated Digital Television
kWh	kilowatt-hour (energy equivalent of 1000 watts of power supplied to or taken an electric circuit over an hour)
LAF	Loss Adjustment Factor

Acronym	Meaning
LCBP	Low Carbon Building Programme
LNB	Low Noise Block converter
mCHP	Micro Combined Heat and Power
MTA	Market Transformation Action
Mtoe	Million tonne oil equivalent
MTP	Market Transformation Programme
NAO	National Audit Office
PrA	Profile Administrator
PV	Photovoltaic
RES	Renewable Energy Strategy
ROC	Renewables Obligation Certificate
R&D	Research & Development
RTD	Real Time Display
SAP	Standard Assessment Procedure
SPM	Supplier Purchase Matrices
TACMA	The Association of Controls Manufacturers
TAHI	The Automated Home Initiative
TRV	Thermostatic Radiator Valves
TOD	Time of Day
TOU	Time of Use
VA	apparent power
VAR	reactive power
VDU	Visual Display Unit
W	active power
WAN	Wide Area Network
VPP	Virtual Power Plant

Smart Meter definition

For the purpose of this project a Smart Meter is defined as an electricity or gas meter which, either on its own or with an ancillary device:

- stores measured electricity and/ or gas consumption data for multiple time periods;

- allows for two way communication;

- allows for remote access to the data collected by the electricity licensee and either the customer supplied by that meter or the customer’s nominated agent.

EXECUTIVE SUMMARY

This report presents the findings of a project undertaken by Enviros Consulting on behalf of Defra. The project considers the potential for behavioural and demand-side management tools to save electricity, gas and carbon in the domestic sector, and the resulting supply-side implications.

In order to do this, we undertook a literature review and a small number of face to face and telephone interviews with industry experts. We drew together the evidence that this research highlighted to quantify three scenarios for energy use in 2020. The report also considers the ways that such outcomes could be delivered.

Introduction

There is a large range of tools that can be used to reduce energy consumption in the domestic sector and to change the nature of that energy demand. These vary from tools used to change behaviours (e.g. feedback on energy consumption), to innovative technologies such as advanced heating controls. Although some of these are already supported by government policy, there is scope to increase that support. This report identifies the tools that can deliver the greatest energy (and carbon) savings and indicates some of the policy routes by which those savings can be delivered.

Tools to deliver energy and carbon savings

The range of tools that could deliver electricity, gas and carbon savings in the domestic sector can be categorised as follows:

- **Information:** i.e. the primary purpose of the tool is to provide the end user with information e.g. energy display units or web forums.
- **Technological tools:** these are pieces of equipment that change the nature of energy use in some way, including e.g. timers.
- **Tariffs:** these can be used by suppliers to incentivise customers to reduce their energy use or to move it to a different time.

Some of these tools are included under the Carbon Emissions Reduction Target (CERT), which runs from April 2008 until 2011. It requires energy suppliers to promote carbon emissions reductions in the household sector. The targets can be met using a range of tools, including energy efficiency improvements, micro generation and energy savings. Taking the analysis into account and the uptake of behavioural and demand-side tools already incentivised by policies like this, we were able to establish the potential for the introduction of ‘additional’ measures[1].

Each of the wide range of tools identified is listed in Table 1, together with an estimate of the energy savings potential of each (from the largest ‘considerable’, through ‘some potential’, to those with least potential classed as ‘limited’)[2]. This estimate takes into account both the scale of impact that the tools could have, their cost effectiveness and the time it would take to implement such an approach.

1 Such measures could be government policies to encourage the uptake of particular tools, for instance.
2 These categories take into account the scope for the implementation of the tools, the extent to which they are already implemented and their current cost effectiveness.

Table 1 Overview of impact of different types of tool

Tool	Potential to deliver additional savings
Information tools: The provision of accurate and timely information is critical to change behaviours and to inform technology choice. It is an important prerequisite for many of the other tools identified and may even have a direct impact on energy consumption. This type of information that is specific to a particular household typically has a much greater impact than untailored or generic information (which consumers may not act on at all). However, that impact may only last for a short period of time or be unpredictable unless it is interpreted and delivered in a way that the energy user relates to.	
Awareness raising	
General and tailored education of consumers and the supply chain: mobilising information so that consumers know how to reduce their energy use and choose efficient products.	Considerable (in conjunction with other tools)
Better billing: including more accurate and regular bills, those that illustrate historical trends or compare energy use against benchmarks, and those that provide disaggregated feedback.	Some potential
Total energy consumption raw data: for instance, electricity meters may display power consumption (kW) at a point in time while gas meters may show gas flow (m^3) over time[3].	Some potential (in conjunction with other tools)
Presentation of interpreted energy consumption data: raw data can be presented to the householder in a more meaningful way e.g. using a real time digital display, ambient signals (like colour or flashing lights); interactive internet sites (like social networking sites) or community websites.	Some potential
Appliance-level consumption data: the contribution of individual appliances can be monitored e.g. using visual display units (VDUs) or even sub-metering[4].	Some potential
Information on efficiency of consumer goods and buildings	
Energy Labels: energy labels can be used to show the relative performance of a particular appliance or building (e.g. using an A to G scale to show energy use compared to its potential or other buildings/ appliances).	Some potential
Procurement advice: advice typically takes the form of information on the most efficient technology models or comparisons of different investment options.	Limited
Information on reducing emissions	
Generic advice on energy reductions: also known as 'mobilising information' this includes tips and facts that help individuals to modify their energy use once they are persuaded it is something they are responsible for.	Some potential
Tailored advice: energy audits: the energy audits provided for larger (e.g. industrial) users can be pared down to provide help and information specific to a particular household.	Limited

3 Such data is a prerequisite for many of the other tools discussed, and so its potential impact is ranked as being higher than, say, real time display units, which similarly do not in themselves trigger a behaviour change but that can be used to facilitate one.

4 Could also be a useful tool for policy maker/researchers etc. There is a need for more appliance level data to better understand both actual performance of appliances and consumer behaviour.

Tool	Potential to deliver additional savings
Technological tools: There are a number of home automation technologies that can be used to optimise energy use in the home or to reduce peak demand. These include passive tools (that once installed do not require any further participation) and active tools (that require input from the building occupant). They can affect electricity, gas or water use and so help save energy and carbon.	
Passive tools	
Heating controls: room thermostats, electronic programmers and thermostatic radiator valves (TRVs) can all help to reduce the amount of energy required to heat a home.	Considerable
Remote control of supply: energy suppliers may have the facility to turn off the electricity supply to a house e.g. at times of peak demand. This facility is used for Economy 7 tariffs.	Some potential
Stand-by elimination: energy use can be reduced either by ensuring appliances are not left on stand-by or by minimising the power an appliance needs when in that mode.	Some potential
Advanced heating controls: in addition to the more commonplace controls listed above, more advanced and innovative technologies can reduce energy use still further e.g. time-proportional, chrono-proportional controls[5].	Some potential
Dynamic demand control: rather than turn off the whole supply, it is possible just to turn off particular appliances remotely e.g. a freezer can be turned off for an hour with limited impact on its functionality.	Limited
Automated lighting: rather than rely on individuals remembering to switch lights off, options like motion sensors and timers can automate the efficient use of lighting.	Limited
Shower heads: modern showerheads can reduce the flow of hot water required hence reducing the amount of energy used to heat it.	Limited
Heat recovery/ exchangers: avoiding wasted heat and making the most of temperature differentials (i.e. transferring energy from outside) can help to maintain the ambient temperature in a home using less electricity or gas.	Limited
Active tools	
Programmable and communicating thermostat: can be used as part of an advanced heating control system. Allows for two-way communication so could receive price signals.	Some potential
Home energy hubs: these combine sophisticated visual display units with the facility to automate appliances. They may be an interim step to smart homes (see below).	Some potential
Smart appliances: appliances like washing machines or freezers an be configured to communicate with remote third parties (e.g. the energy supplier) so that their use can be controlled.	Limited
Smart Homes: incorporates a communications network that allows the (some of) the tools listed above to be controlled, monitored and accessed in conjunction with each other. Can automate control of heating and lighting so not entirely active.	Limited

5 These monitor how quickly the room heats up and more controls boiler output more tightly than a standard thermostat, resulting in less fluctuation about the target temperature.

Tool	Potential to deliver additional savings
Tariffs: Energy prices can be used to incentivise householders to: use less energy; limit their demand at any one time; or to change the time of day they use it. This impacts on carbon emissions both through the direct use of fossil fuels in the home (in the case of natural gas) or indirectly (by affecting the nature of centralised generation required and the operation of the energy distribution networks).	
Time of Use (TOU): time of use pricing encourages individuals to switch their electricity use to off-peak periods (e.g. overnight or at the weekend) by charging a higher unit price at peak times.	Some potential
Interruptible contracts: users that are prepared for their electricity supply to be disconnected for short periods ('interrupted') may be offered a discount. This allows energy suppliers to control demand at peak periods.	Some potential
Increasing block tariffs: these require users to pay more per unit of energy the more that they use. If used in conjunction with time of use tariffs for electricity (see below), the unit price could reflect both the quantity and timing of energy consumed.	Limited
'Pay as you go': prepayment tariffs allow the user to manage their energy use closely and by limiting the amount used to the credit available e.g. by using a key meter or key pad.	Limited

Impact of existing policies on the uptake of these tools

A large number of government policies aim to improve energy efficiency and reduce carbon emissions in the domestic sector. Initiatives that target other goals e.g. fuel poverty or low carbon transport may also affect energy use in the home. In some cases these other policies enhance energy savings; in others they may actually increase the energy use of householders, or, at least, result in them switching consumption from one energy source to another.

The table below describes the range of policy impacts identified and provides some examples of the policies in place that have those impacts. In the table, the impact is expected to affect baseload and peak energy use, unless specifically stated that it only affects peak use. It relates to existing homes; the energy efficiency of new homes is governed by a number of policies, including (but not exclusively) building regulations, the code for sustainable homes, zero carbon homes and stamp duty on zero carbon homes.

Table 2 Summary of impacts of Government activities

Impact on energy demand	Description of impact
Improved energy efficiency in homes by installing tools e.g. Warm Front, Fuel Poverty Action Programme, CERT, landlord energy saving allowance, Decent Homes, reduced VAT on energy saving materials	Reduced energy (electricity and gas) use for heating in households (in the absence of comfort taking)
Improved information on energy efficiency of homes e.g. Energy Performance of Buildings Directive (EPBD), Energy Performance Certificates (EPCs)	Provision of information on energy efficiency of homes Increased awareness of climate change Potential to affect house prices differentials and incentives to install tools (see row above)

Impact on energy demand	Description of impact
Improved information to end users about their own energy use in homes e.g. policy linked to the Directive on Energy End-Use Efficiency and Energy Services (ESD)	Provision of historic information (in graphical form) on energy users' bills Greater awareness of electricity and gas use (Expectation that will) reduce energy use
Greater availability of generic information about domestic sector energy use e.g. ActOnCO2, Climate Change Fund, Energy Saving Trust's advice centres, Green Home Service and on-line Home Energy Check etc.	Provision of typical/ average historic information on energy users' bills Greater awareness of how electricity and gas use affects CO2 and reductions by some concerned households
Improved energy efficiency of products e.g. Product ban on incandescent bulbs, Eco-Design of Energy Using Products Directive, EST energy saving recommended scheme	Reduced electricity use (including stand-by power)
Improved information about energy using products e.g. EU Energy Labelling Scheme, Market Transformation Programme	Provision of energy labels and supporting information More informed choice of lower energy consuming appliances (and heating equipment)
Greater uptake of non-renewable microgeneration (combined heat and power, CHP) in homes e.g. Microgeneration Certification Scheme (MCS) and EST Green Home Service.	Energy generation on-site at home Reduced electricity import from grid Increased natural gas use.
Other microgeneration (for electricity or heat) e.g. Low Carbon Building Programme (LCBP), feed-in tariffs	Energy generation on-site at home Reduced electricity or gas import from grid
Price signals affecting energy costs e.g. EU ETS, VAT	Higher energy costs and so stronger price signal to reduce energy use
Greater uptake of electric vehicles and plug-in hybrids e.g. road tax, congestion charging, company car tax differentials	Charged up via domestic electricity supply (In the absence of measures to encourage off-peak charging) increase in baseload and peak electricity demand, cars could provide energy services such as back feeding at peak i.e. act like a battery for the house.
Improved water efficiency in homes e.g. Code for Sustainable Homes, Market Transformation Programme	Reduced energy use
Improved and increased waste recycling in homes e.g. EU Landfill Directive, Local Area Agreements	New potential renewable energy supply Increased awareness of climate change (and potentially energy use)

The table above highlights the wide-ranging scope of the government initiatives already in place. However, our review of these policies has identified some policy gaps, i.e. instances where there is still scope to encourage additional uptake of the types of tools identified. This is in part due to the historic focus on policies that focus on a relatively small group of energy savings measures (e.g. cavity wall insulation) or on product standards. There remains untapped potential e.g. to encourage the uptake of behavioural tools and this could be driven by Government support.

Quantification of energy savings

In order to establish the areas to focus on, we have quantified potential savings in a range of scenarios. We have taken BERR projections as a starting point – the scenario used assumes the full delivery of existing firm and funded energy/ carbon saving policies. In order to quantify the additional potential to reduce electricity and gas consumption in the domestic sector using the tools described above, three hypothetical scenarios were developed:

- **Scenario 1 'Additional Measures'**: this reflects a world where additional policies are put in place to encourage increased uptake of cost effective tools. It reflects the idea that even where savings are cost effective, there may be barriers to their uptake. This scenario has the lowest level of energy savings of the three scenarios but still assumes action above and beyond the full delivery of policies already in place.

- **Scenario 2 'Idealistic'**: this reflects the level of savings that could be achieved if all tools that have a relatively short payback period or that do not have prohibitively high upfront costs are implemented. Achieving this scenario would be even more challenging than either the 'full delivery of existing measures' or the 'Additional Measures' scenarios above.

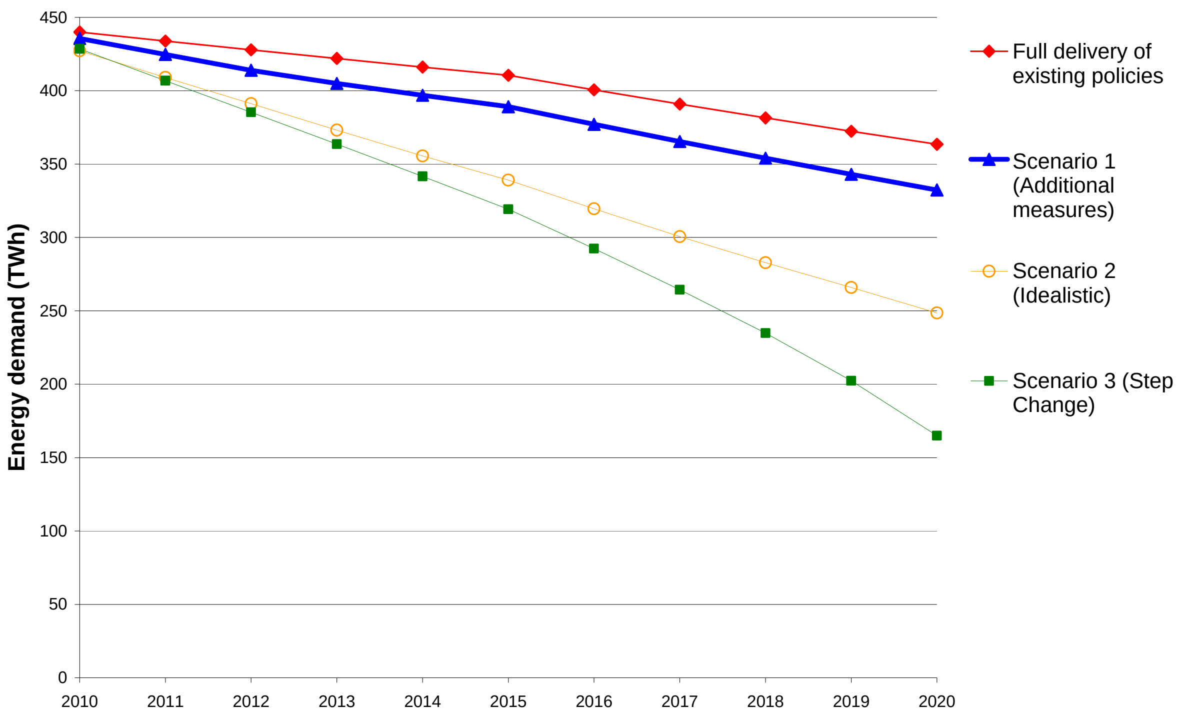
- **Scenario 3 'Step Change':** this considers the maximum level of energy savings[6] that could be achieved. This would be extremely challenging since it would require not only changes in behaviour, but also the uptake of tools with relatively long payback periods. It assumes that tools deliver their full technical potential.

The savings resulting from both technological and behavioural change over and above those assumed to be delivered by existing firm and funded policies were quantified for each scenario. The resulting energy demand is shown in the chart below. It shows that the Step Change scenario delivers a 55% saving in electricity and gas use by 2020 compared to the projected consumption under full implementation of existing policies. The Idealistic case would deliver a 32% saving and the Additional Measures scenario only 9%. This compares to the UK target for energy efficiency in the domestic sector (set in the Housing Act 2004), aims to improve residential energy efficiency by at least 20% by 2010 from a year 2000 baseline.

It should be noted that these scenarios have not taken into account so-called macro economic rebound effects, whereby financial gains from spending less on energy result in greater spending on other activities. Evidence (from UK ERC) suggests that between a third and a half of emissions assumed saved may be lost in terms of higher emissions across the economy.

6 Energy rather than carbon savings. The increased uptake of renewables could help reduce carbon. In addition fuel switching could also reduce carbon.

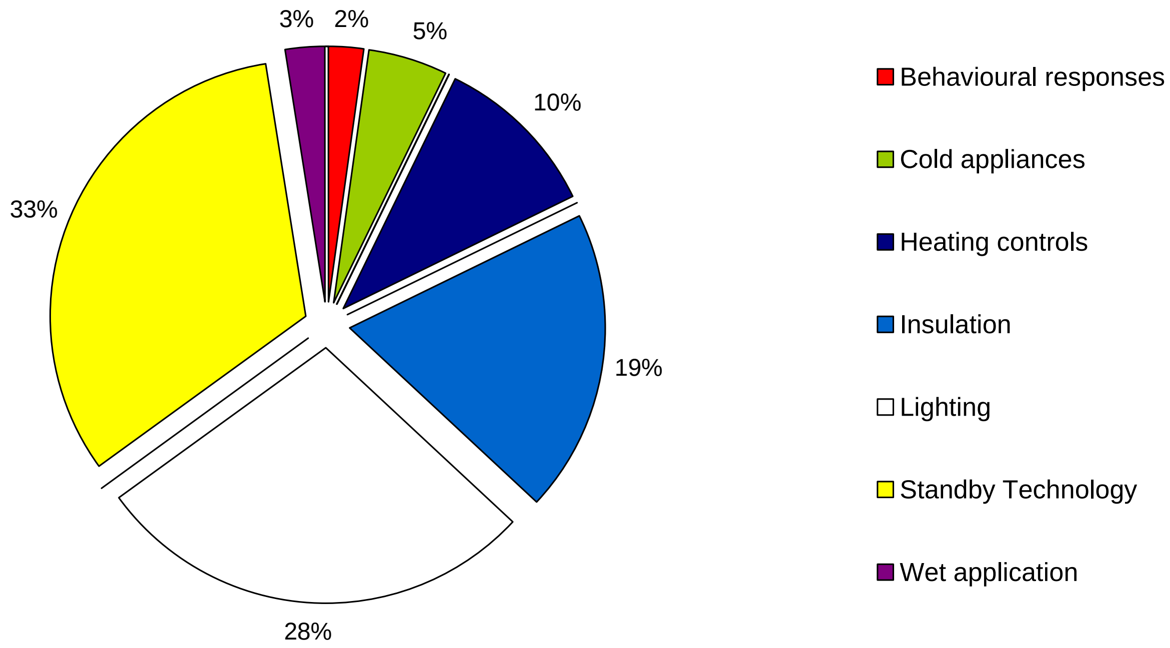
Figure 1 Energy (gas and electricity) demand under each scenario



The top three sources of energy savings: were: technical reduction of stand-by, installing insulation (over and above that which is expected to be installed under existing policy e.g. for solid walls) and improved heating controls. Increasing the efficiency of lighting also results in significant carbon savings.

The diagram below shows the contribution of the different measures to delivering the energy (gas and electricity) savings in 2020 for the Additional Measures scenario (compared to the full delivery of existing policy scenario). It can be seen that behavioural measures account for only 2% of the reductions in the Additional Measures scenario but this rises to 6% and 17% in the Idealistic and Step Change scenarios (respectively).

Figure 2 Split of energy savings by measure for Additional Measures scenario (2020)



Quantification of carbon savings

These energy reductions would also result in carbon savings. These savings would be both direct in the domestic sector where natural gas use would fall, and also indirect (i.e. at the power station) where electricity consumption is reduced[7]. The table below summarises the carbon emissions projected. Although carbon emissions fall over time in all three scenarios, this is not to the same extent as energy (due to the higher carbon intensity of electricity when compared to natural gas) as shown in Table 3 below.

Table 3 Emissions reductions ($MtCO_s$) per year under each scenario (snapshot years) compared to emissions under full implementation of existing

Scenario	Fuel	2010	2013	2015	2020
Scenario 1 (Additional measures)	Gas	0.1	0.6	1.0	1.8
	Electricity	1.7	5.9	7.0	9.4
	Total	**1.7**	**6.6**	**8.0**	**11.2**
Scenario 2 (Idealistic)	Gas	1.3	4.3	6.3	10.6
	Electricity	2.5	11.2	16.6	25.3
	Total	**3.9**	**15.5**	**22.8**	**36.0**

7 Note that all the scenarios assume only a relatively modest uptake of renewables, since their focus is on energy saving rather than fuel switching. Additional carbon savings could be made were the electricity and heat demand serviced by additional renewables.

Scenario	Fuel	2010	2013	2015	2020
Scenario 3 (Step change)	Gas	0.8	5.7	9.1	23.8
	Electricity	3.1	12.1	18.7	31.6
	Total	**3.9**	**17.9**	**27.8**	**55.3**

Supply side impacts

By optimising the amount, type and timing of energy used in the home, some of the measures described above can also have an impact on energy supply (both electricity and gas). If the penetration of any of these measures is significant and is not offset by other factors, then these impacts would need to be accommodated by the energy supply chain. The supply-side impacts identified are as follows:

- **Reduced annual demand:** energy savings measures reduce the total volume of energy (either electricity or gas) required over the particular year. This can result in reduced use of more expensive energy sources and a reduction in the number of units of energy sold. It can change projections of energy demand and so the amount of new generation capacity required.

- **Fuel switching:** measures that encourage fuel switching e.g. from electric heating to gas, may result in an increase in demand for a particular type of fuel at a particular location, even if there is a net reduction in the total volume of fuel required overall.

- **Peak load reduction:** measures that shift the time at which energy is used may not reduce the amount of energy required in a year, but instead can shift demand and so influence the level of peak demand.

  - This may allow peak electricity generation and to be used less often, so displacing more expensive energy sources. Although this project has not involved dispatch modelling or projections of generation mix, peak load reductions could result in carbon reductions if they displace more carbon intensive plant[8].

  - Energy networks and generation capacity are designed to ensure security of supply during annual peak demand periods. If the change in demand profile is sustained over the long term, it may affect the capacity required to service peak demand and so affect the nature and amount of investment required.

- **Reduced network demand and reduced losses:** the uptake of microgeneration that is embedded in the distribution network will reduce a household's electricity import from the network and may also reduce its gas imports[9]. It may also (depending on the household's demand profile and how the equipment is sized) result in electricity exports to the network. This affects the volume of electricity that needs to be generated by transmission connected plant/ serviced by the gas transmission system, and can also reduce transmission and distribution losses.

8 Peaking plant for electricity (e.g. open cycle gas turbines, OCGTs) can be more carbon intensive than baseload plant (as a result their efficiency or their reliance on higher carbon fuels like oil or both).

9 Increased uptake of gas-fired micro combined heat and power (CHP) would increase gas demand.

- **Network management:** Introducing initiatives that allow domestic sector demand to be more closely measured, monitored and controlled provide significant scope to better manager the electricity (and gas) networks. This could reduce costs and potentially carbon emissions.

- **Data availability:** In addition to informing the end-user, the collection of better (i.e. more detailed, accurate and timely) data on energy use can also have benefits for third parties such as suppliers and grid operators. It may allow for markets to operate more efficiently, e.g. via more innovative tariff offerings and opportunities for advanced grid management.

These changes to the use of gas and electricity demand across the year and at peak times affects carbon emissions from the energy supply industry and also potentially its costs. For instance, it is estimated[10] that peak electricity demand per household could be reduced by 45% from 0.94kW to 0.42kW through the introduction of more energy efficient appliances[11] and by a further 0.09kW by avoiding energy use at peak by using a combination of automation and time of use tariffs. Were this to be the case it would reduce the maximum load that the networks and generation fleet need to be designed to meet in order to ensure security of supply[12]. It could significantly reduce system losses and facilitate better management of the grid, (which will become particularly important as the penetration of intermittent generation increases).

Role of smart metering

Although smart metering[13] is not essential for all of the policies in place or to encourage the uptake of some of the measures identified, it would facilitate and enhance the savings delivered by many of them. As smart meters are introduced, care should be taken to ensure that they meet the technical specifications that enable access to the full range of benefits offered by the tools.

Key features that any domestic meter would need to exhibit to deliver the maximum benefits identified above include:

- display units that provide direct consumer feedback where the customer can readily see it, and that is presented in a way that engages the household;

- advanced meter management (AMM) functionality to allow for access to all the benefits mentioned above (including flexible tariffs);

- being flexible for new technology developments[14] since the roll-out process will take a number of years and technology may move on.

10 For the Step Change scenario described above.
11 For some uses; we have not assumed complete replacement of all the existing stock (see Appendix 5 for further details).
12 It could also reduce the use of carbon intensive peak capacity. However, based on Government guidance all carbon savings in this report have used the emissions factor that relates to the long-term marginal plant (a gas-fired CCGT).
13 For the purpose of this project a Smart Meter is defined as an electricity or gas meter which, either on its own or with an ancillary device that: stores measured electricity and/ or gas consumption data for multiple time periods; allows for two way communication; allows for remote access to the data collected by the electricity licensee and either the customer supplied by that meter or the customer's nominated agent.
14 For example they should be able to communicate with appliances in a Home Area Network.

In addition, ownership of the data is crucial; in addition to information being available to the householder, some of the tools require that energy suppliers and other third parties also be allowed access to the information. We would expect that who has access to the information would be at the discretion of the energy user. Key outstanding questions are around meter ownership, stranded assets and interoperability standards.

The table below illustrates how smart meters can be used in conjunction with information and awareness raising approaches to change behaviours and to incentivise reductions in energy use. As an example, it then sets out how combining a smart meter with a real time display (RTD) could affect energy use. Lastly it shows the impact that combination with additional tools (smart plugs or appliances) could have.

Figure 3 Illustration of potential role of smart metering when combined with other tools

	Technology	Energy and/or carbon savings achieved by
1	Smart meter	More frequent bills for electricity and gas e.g. monthly
		Historic comparisons of energy consumption on bills
		Comparisons with ‘norms’ or benchmarks on bills
		Advice from energy supplier or other third party based on analysis of energy use
		Increased use of pay-as-you-go tariffs
		Websites to see more detailed graphs etc of individual consumption
		Time-of-use tariffs to shift demand
2	Smart meter + RTD	Real-time information on electricity use
		Daily cumulative data on gas use
		Alerts if consumption exceeds thresholds
		Social networking sites to share info and compete
		Alerts about microgeneration output to prompt use of appliances
3	Smart meter + smart plugs or smart appliances + RTD	Detailed consumption information about individual appliances
		Appliances automatically disconnected by the supplier at peak
		Touch screen control of appliances to switch them on/ off

Note that the combinations shown in the table above are cumulative, that is the third option could in principle result in all of the outcomes listed. It is also not exhaustive; for instance, smart meters could also be used in conjunction with e.g. energy audits or heating controls to deliver savings in other ways.

As stated above, smart metering is not an essential for all of the policies in place but would be beneficial for many of them. For example, understanding how much energy is consumed by different appliances might encourage people to buy more efficient goods and one way of achieving this is through the provision of more timely and accurate information. However, the smart meter alone would not deliver these changes particularly not if its display is not easy to interpret and it is not in a prominent position in the home. Key to affecting choices and decisions is communicating the information, which could be achieved using smart metering if data is sent to through e.g. a VDU, phone or website.

Given the relatively long time scales involved in smart meter roll-out it is key that other measures are promoted in the interim period. For example feedback can be increased via better billing[15] and technologies such as smart plugs and appliances can be used without smart meters.

Scope for Government intervention

Given the scope for additional carbon savings highlighted in the Step Change scenario above and the findings from the policy mapping exercise, there is scope for additional government intervention. We understand that this could be in the form of extending the Carbon Emissions Reduction Target (CERT) (i.e. increasing the level of activity required of energy suppliers).

Our modelling shows that the following areas offer significant additional savings:

- Insulation (including greater uptake of e.g. cavity wall and loft insulation, plus types of insulation less supported to date e.g. solid wall insulation) – this could, for instance, be driven through the extension of CERT.
- Consumer electronics – the uptake of efficient electronic goods is partly driven by CERT and also targeted by the Market Transformation Programme (MTP). There is a need for better labelling at the point of purchase.
- Heating controls – retrofit of controls is driven by CERT and building regulations but could be accelerated. Credit for both retrofit and advanced controls under CERT and the Standard Assessment Procedure (SAP) needs to be revised.
- Behavioural response – there is a need for awareness raising and general education, some of which is already underway. Key is that information is targeted at and tailored to particular audiences. As a result, this may be best delivered through package of targeted measures depending on the audience/ aims.
- Smart meters – a technology that could enhance savings from the above, subject to the right incentives being placed on energy suppliers, in particular, to deliver the full environmental benefits.

These changes can be delivered with the help and support of a range of different agents, all of which can have a role.

- Energy suppliers: energy suppliers enter into regular communication with householders via their energy bill. Information provided by the bill can help inform customers. Innovative tariff and service offerings can also help suppliers retain customers and potentially reduce the costs to serve. As a result, there is a role for policies like CERT, which use energy suppliers as the delivery route to achieving savings.
- Network operators: these organisations have an interest in the optimal operation of the network, in anticipating changes in the nature of demand and energy generation. The potential for charging structures and pricing schemes to provide the ‘right’ incentives to domestic customers in a liberalised market should be explored.

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15 Views on the role of clip-on real time displays as an interim solution to provide better feedback on consumption are mixed. Some people think they could be beneficial (for some sectors of the population) whilst others think have limited potential.

- Publicly funded bodies (e.g. Energy Saving Trust): there is some evidence that energy users have greater trust in information from organisations that they consider to be 'independent'. Such bodies consequently have a crucial role in information provision.

- Private bodies (e.g. landlords, management companies, property developers): one of the greatest challenges to delivering policy in the domestic sector is the large number of households and the relatively small energy use of each. Organisations that are responsible for groups of new and existing houses could help to facilitate increased uptake of improvements.

- Education sector (including specialist training): improved awareness of the opportunities for and benefits of better household energy management could be delivered via a range of routes. Providing training not only for those that are in full- or part-time education, but also for those undertaking specialist training, is one way to convey information to both energy users and the supply side.

Long term outlook

The analysis above refers to the period up to 2020. When we look at a longer period of time, there is even greater potential to reduce carbon emissions from the domestic sector (although the uncertainty around the impacts also increases[16]). Such change can be effected by:

- achieving engagement amongst individuals by persuading them to take responsibility for their actions – 'engaged citizens' will be those that are motivated to act;

- providing individuals with the information and tools ('mobilising information') that they need to take action, whether that be lifestyle changes or investing in energy saving technologies;

- ensuring that new homes make the most of the technologies available, via both building design and their fit-out - while some homes could use sophisticated technologies and networks other homes could contain basic design features that make them very low energy and appeal to different individuals;

- facilitating the retrofit of existing households with energy efficient equipment so that 'engaged citizens' are able to adapt their lifestyles and behaviours to save energy.

16 In part because we are less certain about how energy savings technologies may develop, but also because little evidence exists to show how behaviours can be influenced in the long term. It also be comes more difficult to anticipate how other drivers for energy use will change. For example, the introduction of new activities or practices is likely to influence what householders use energy for and their propensity to make energy efficient choices.

1. INTRODUCTION

This report by Enviros Consulting looks at the potential for behavioural[17] and demand-side management measures to save electricity, gas and carbon in the domestic sector, and the resulting supply-side implications. It considers a range of measures that can be used to reduce consumption and also to change the nature of that demand[18]. These vary from increased feedback on energy consumption which can help to change behaviour, to innovative technology such as advanced heating controls. We consider what level of savings could be achieved to 2020 and what is required to get there.

1.1 Project context

Given the severity of the threat of climate change, the UK Government's stated ambition to reduce greenhouse gas (GHG) emissions by 60% by 2050, and the fact that individuals are responsible for a significant proportion of UK carbon emissions, there is a need to better tap into the abatement potential that households can provide.

A wide range of tools are available to reduce electricity and gas use in the home and awareness around their potential is increasing. However, the potential for measures that rely on individuals' behaviour to deliver sustained energy/ carbon reduction is less well understood than the impact of permanent measures like insulation. In particular, for behavioural measures to be a successful policy tool, it is important that individuals react to any incentive in the way that is expected and that that behavioural change continues over the long term.

1.2 Project aim

The purpose of this project is to better understand the contribution that smart metering and other domestic energy management options, including smart metering, can make to the UK's carbon reduction targets in the period to 2020. It aims to identify how cost-effective carbon savings (and the associated benefits) from behavioural and energy management measures can be maximised.

In summary, the main objectives of this project are to establish:

- how 'best' to deliver energy (electricity and gas) savings by influencing behaviours; the definition of 'best' considers both cost effectiveness[19], volume of (energy and carbon) saving and also the timescale within which the savings could be delivered;
- how 'much' energy can be saved through these measures, when those savings may happen and so how much carbon they might save (e.g. will they facilitate peak-lopping, baseload reductions or influence shoulder periods?);
- the certainty and consistency with which these savings could be delivered;

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17 This report does not include a full discussion of behavioural change theory. As such it should be read in the context of wider ongoing research into behavioural change.
18 e.g. in terms of fuel type or time of use.
19 Cost effectiveness was based on payback periods only. A full cost benefit was not undertaken.

- the way in which the increased uptake of such measures could impact on other policies (e.g. for energy security, the uptake of renewables) and interact with measures already in place.

1.3 Project approach

The approach to this project is summarised in the table below. :

Table 4 Project approach

Approach type	Task number	Task description
Qualitative	Task 1a	Collation of existing evidence
	Task 1b	Review of different implementation options – behavioural and energy management measures Review of policies interactions with household energy use
	Task 1c	Review of barriers to uptake (including stakeholder interviews)
Quantitative	Task 2a	Review of energy savings under different implementation options
	Task 2b	Review of carbon savings under different implementation options
	Task 2c	Highlight impact of smart metering

Evidence for this report was gathered during a literature review and in person or telephone interviews with a number of experts in the field.

1.4 Structure of this report

This report is structured as follows:

- In Section 2 we set out the range of measures that could potentially be used to reduce energy and carbon emissions from domestic sector that are considered for the purposes of this study.
- In the sections that follow (Section 3 to Section 6) we discuss the different ways that these measures can be implemented and present any evidence of savings that the literature review has identified[20].
- We summarise the findings from the sections above in Section 7 and draw out the extent to which these measures have the potential to save energy in the short term.
- In Section 8 we discuss the different policies that impact on energy use in the domestic sector and identify possible gaps where policies may not result in maximum uptake of the measures discussed.
- The scenarios modelled to estimate the potential impact of the measures on energy and carbon emissions are set out in Section 9 (with additional detailed outputs in Appendix 4.

20 We have provided additional information e.g. around the background to behavioural measures where requested by Defra in response to the interim report.

- Section 10 discusses supply side impacts of behavioural and demand side measures i.e. impacts on the generation network and gas grid. The impact on the supply side is also quantified.

- Section 11 looks at how the additional reductions from full delivery of existing policies scenario modelled could be achieved – what are the barriers and how can they be overcome?

- Finally in Section 12 we consider what factors might influence energy consumption and carbon emissions beyond 2020.

The Appendices contain the references that we have reviewed, a list of the interviewees, descriptions of the methodology used in the quantitative analysis and further information on passive homes.

SECTION 1: INFORMATION ABOUT BEHAVIOURAL AND DEMAND SIDE MEASURES

2. TOOLS TO REDUCE ENERGY USE IN HOUSEHOLDS

This section of the report explores the various technological and behavioural measures[21] that can be used to reduce electricity and/ or gas use and carbon emissions from households in the UK. This forms the focus for the quantitative analysis that follows.

This study focuses on measures outside of the energy obligation on energy suppliers, the Carbon Emissions Reduction Target (CERT), which aims to promote reductions in energy use and carbon emissions in the household sector. The study does however consider a number of measures that may be included under CERT, but that have either only recently been proposed for inclusion, or that are expected to have limited uptake under CERT[22].

2.1 How can energy use and carbon reductions be delivered?

The measures considered for this project are those that can reduce electricity use, gas use and carbon emissions from the domestic sector. This can be achieved in a number of ways, by:

- reducing a household's baseload and peak consumption of electricity or gas by:
  - using more efficient appliances and heating systems;
  - using appliances and systems more efficiently;
  - turning off appliances when they are not in use;
- reducing a household's consumption of electricity or gas at peak by controlling the time of day at which they are used[23];
- reducing the carbon intensity of the energy used:
  - e.g. by introducing renewables, microgeneration or fuel switching between fossil fuels.

2.2 Measures considered for this project

In order to establish the full range of ways that energy savings could be delivered in the domestic sector, we have drawn up a list of measures that could be applicable[24]. We have categorised the measures into the following four groups listed below.

- **Measures eligible under CERT:** we have separated these out since for the quantitative analysis in the later stages of the project, we consider whether savings delivered from these particular types of measure are 'additional'[25].

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21 'Measure' refers to a tool that helps reduce energy and/or carbon emissions whether in the form of a technological solution or improved information.

22 For example both retrofit and advanced heating controls are discussed in the section on technological tools as there has been considerable recent innovation in the sector and the uptake of heating controls under CERT is expected to be limited.

23 Reducing peak consumption could reduce carbon emissions – see section 10 on supply side impacts.

24 The starting point was the list of measures set out in Defra's Illustrative Mix under the CERT which we then built on via the literature review.

- **Information:** this is where the primary purpose of the measure is to provide the end user with information e.g. energy display unit or web forums.
- **Technological tools:** these are pieces of equipment that change the nature of energy use in some way, including timers.
- **Tariffs:** these can be used by suppliers to incentivise customers to reduce their energy use or to move it to a different time.

The measures that we have categorised under each of these four areas are discussed in turn in the sections that follow. There are several cases where measures overlap between these three categories[26].

2.2.1 Measures under Carbon Emissions Reduction Target (CERT)

CERT specifies a number of accepted measures, 'standard actions' set out in Defra's Illustrative Mix, the carbon savings of which have been quantified[27]. They include those listed in the table below[28]. However, this list is not exhaustive as suppliers can also use 'demonstration' measures where it has not been previously possible to determine carbon saving, to meet up to 6% of their obligation[29]. It has been proposed that this is increased to 10% as part of the changes to CERT put forward as part of the fuel bills initiative.

Table 5 Energy management and behavioural measures under CERT

Type of measure	Example
Insulation	Cavity wall insulation
	Loft insulation
	Solid wall insulation
	Insulated wallpaper
	Hot water tanks jackets
	Draught proofing
	Glazing
Efficient heating	Boiler replacement
	Radiator panels
Fuel switching	e.g. from coal to natural gas
Heating controls	Upgrade
	Extra

25 It is proposed that a number of additional technical and behavioural measures (energy audits and real-time electricity displays) are included in CERT with early action qualifying for credit. This is subject to consultation. However, only a limited rate of uptake can be achieved under CERT and therefore further uptake of these measures would be additional.
26 e.g. Some tariffs require technological change e.g. Economy 7 tariff requires the installation of a new meter.
27 The carbon saving resulting from these measures are based on the lifetimes set out in the Illustrative Mix of measures.
28 List taken from Defra's Illustrative mix and/or the Ofgem guidance for suppliers (Ofgem, 2008a).
29 The lifetime of these measures has to be determined on a case by case basis.

Type of measure	Example
Good quality combined heat and power (CHP)	Natural gas
Biomass	Boilers / CHP
Energy efficient light bulbs	Compact Fluorescent Lamps (CFLs)
	Efficient halogens
	Sensor Lamps
Efficient white goods	e.g. washing machines or fridges
Efficient consumer electronic / brown goods	Integrated Digital Televisions (iDTVs)
	Energy savings kettles
Computer mains panels	e.g. to turn off peripherals when computer turned off
Low noise block downconverters (LNBs)	e.g. for satellite dishes
Microgeneration	Solar water heater
	Ground Source (GSHP)
	Micro/ mini wind
	Micro hydro
	Photovoltaics (PV)
	Micro CHP (mCHP)[30]

The new £900 million package of energy efficiency measures announced by Government on 10 September 2008 includes a proposed increase in the existing CERT obligation with a wider range of efficiency measures to qualify under the existing CERT obligation. The existing CERT target may be increased by 20% up to March 2011. The proposed new eligible measures are:

- energy efficiency audit with home visit and advice provision; and
- real time display units.

The Government announcement also included a new community based initiative targeted at the lowest income groups[31].

In addition the proposals include an inflated score for loft insulation top-up. The ring-fenced fund for innovation (which covers Market Transformation Action (MTA) and Demonstration Action (DA)) may be expanded by 50% and the newly qualifying measures may be given a 50% uplift until the fund runs out.[32]

30 Currently unproven technology. Trials run by Ofgem showed that micro CHP only saved energy when used in a large house where the occupants were typically home all day, in other types of house there was often an increase in use.

31 This is billed as a separate Community Energy Savings Programme of energy efficiency measures targeted at the country's poorest communities. It is funded through a new and additional obligation on the energy suppliers and electricity generators so is also part of newly extended CERT.

32 MTA and DA are collectively capped at 6% of a supplier's obligation (or 8% if the supplier achieves at least 2% through microgeneration measures), then uplift of 50% is then applied.

2.2.2 Information measures

The provision of accurate and timely information may have a direct impact on energy use. However, that impact may only last for a short period of time or be uncertain if it is not interpreted and delivered in a way that the energy user relates to. Raw data is valuable in its own right in that it is an important prerequisite for many of the other measures identified.

We have grouped the types of information that may have an impact on energy use as follows. A list of measures under each of these categories is provided below.

- **Increased awareness and understanding of climate change** What is the problem? The provision of this information helps to prime individuals to use energy savings measures and to support their importance, and helps to tackle sceptics/ misinformation.. However for many individuals, this alone will not result in either attitudinal or behavioural change towards energy use.

- **Increased awareness of impact of individual/households on climate change** What are the main emission sources associated with my house? What is my actual energy consumption? Once a person is aware of climate change and is motivated to act, there may be a need for further information on how to act appropriately (this is sometimes referred to in the literature as 'mobilising information')[33].

- **Information on reducing emissions** How do I reduce the emissions associated with my house? Many users want information on what they should do to reduce energy bills and carbon rather than necessarily to understand the details of why. Lists of 'quick wins' and other guidance (e.g. to wash washing at 30°) falls into this category.

- **Information on efficiency of consumer goods and building** How do I pick the most efficient house or appliance? Energy labels for appliances and buildings, and support from organisations like the Energy Savings Trust (EST), provide examples of the types of measures that fall into this category.

Table 6 Energy management and behavioural tools - Information

Aim	Type	Sub-type	Examples
Increase general awareness of Climate Change	General education		Climate Change Communications Initiative[34]

33 The need for better feedback on energy consumption is reflected by the European Energy End-use Efficiency and Energy Services Directive (ESD) which sets out requirements for improved metering and billing. Increased feedback can be provided in a number of ways including better billing, visual display units showing real time electricity consumption, and the presentation of consumption data on a community website.

34 The campaigns may be delivered through a range of different media (interactive websites, advertising campaigns etc.) For example the 'Act on CO2 calculator' part of the Government's Climate Change Communications Initiative, aims to raise awareness of climate change, quantify an individual's carbon footprint and provides tips on reduction techniques.

Aim	Type	Sub-type	Examples
Increase awareness of impact of individual/household - identification of emission sources / quantification of GHG emissions	General education		BBC Bloom, Big Green Switch, Act on CO2 calculator, Supplier on-line calculators
	Better billing	Historical trends	Norway
		Benchmarking	
		Disaggregated feedback	
	Total energy consumption raw data	Current only (KW) used to calculate energy (kWh)	UK meters
		VAR used to calculate energy (kWh)	Italy
		Gas flow (m^3) – typical heat value used to calculate energy	UK meters
	Appliance level consumption data	Profiling of individual appliances	Intrusive and non-intrusive monitoring possible
	Presentation of interpreted energy consumption data	Internal (in house)	Visual Display Units
		External (remotely)	Software/websites using output data e.g. Chatham-Kent Hydro (Go Figure website), Holmes, Green Streets website
Provide information on efficiency of consumer goods and buildings	Energy Labels	Appliances	Energy Star, white goods labelling
		Building	Energy Performance Certificates
	Procurement advice	List of energy efficient models	Energy Saving Trust - Energy Saving Recommended / Market Transformation Programme (MTP)

Aim	Type	Sub-type	Examples
Provide information on reducing emissions	Generic advice on energy reductions		Network of Energy Saving Trust advice centres.[35]
	Tailored advice: energy audits	Home visits	E-ON Energy Saving Challenge
		On-line surveys using data inputted by customers	British Gas - Energy Savers Report. EST Home Energy Check,

2.2.3 Technological tools

There are a number of home automation technologies that can be used to optimise energy use in the home or to reduce peak demand. These can be grouped into:

- passive measures – once installed these measures do not require any further participation from building occupant[36] (i.e. they become the 'norm'); and
- active measures – tools that enable people to optimise energy use but require input from building occupant (therefore involve an element of behavioural change).

The measures can also be grouped on a temporal basis relating to the time period over which their savings are delivered i.e. into dynamic (short term) and static measures (long term) (Bilton et al, 2008).

There are three kinds of resource use that these tools can optimise:

- electricity – by turning off appliances when not in use or during peak demand periods;
- natural gas – by increasing the effectiveness of heating systems or controlling them to ensure that a building is maintained at the correct temperature;
- hot water use – by reducing hot water flow and so saving energy consumption[37].

35 The Energy Saving Trust (EST) is the main provider of advice to the domestic sector on energy efficiency and microgeneration technologies. It runs a number of initiatives including publicity campaigns, a website with a number of publications and guides, phone line. It also administers a number of grant programmes such as the Low Carbon Buildings Programme.

36 Some of these still require individuals to operate, e.g. basic heating controls.

37 Only technologies that reduce hot water consumption have been included in Table 5 as whilst reducing water consumption has an indirect affect on carbon emissions (through reduced water and sewage treatment) the generation of hot water has a far greater direct impact on the carbon emissions produced by the domestic sector.

Table 7 Energy management and behavioural measures – Technological tools

Participation	Energy type	Type	Examples
Passive	Electricity	Remote control of supply	Economy 7 heating[38]
		Dynamic demand control	No in situ and fully functioning example found but the technology exists
		Automated lighting	Motion sensors
			Timers
		Stand-by elimination	Bye Bye Stand-by, Intelliplug, PowerSafer, CheckTap
	Space heating	Advanced heating	Radiator booster, Radiator valves, programmable and communicating thermostats etc.
		Heat recovery / heat exchangers	MTD Heat / Energy Recovery Ventilation System, Rehau (manufacturer) - 'Awadukt Thermo' (product
	Hot water	Shower heads	Flowpoint (various products)
		Heat recovery / heat exchangers	As above
Active	Electricity	Home energy hub	GEO (Trio)
	Electricity	Smart Appliances	None currently on market however research projects such as Smart Domestic Appliances in Sustainable Energy Systems (Smart-A) project currently under way.
	Space heating, electricity	Home control system / Smart Homes	Homemanageables, SmartOne Home Control System, INNOVUS - home control device

'Smart homes' can feature a number of passive and active features and can control lighting, heating/cooling systems and appliances. See Section 5.3 on smart home technology below.

2.2.4 Tariffs

The last category is innovative tariffs which can be used to incentivise people to: use less energy; limit their demand at any one time; or change the time of day they use it at. The use of Time of Use (TOU) tariffs which incentivise consumers to switch electricity consumption to different times of the day are a useful demand side management (DSM) tool which can result in carbon savings in a number of direct and indirect ways (see Section 10 on supply side impacts). The different types of tariffs are identified in the table below, along with some examples.

38 In conjunction with tariff – see financial section below.

Table 8 Energy management and behavioural measures – tariffs

Type	Example	Sub-type 1	Example
Tariffs	Pay in arrears	Increasing block tariffs	Flemish part of Belgium
		Time of Use (TOU)	Economy 7
		Lower rate for lower security of supply (interruptible) / interruptible appliance	Hot water heaters in South Africa
	Pre payment tariffs	'Pay as you go'	key meters/key-pad meters

The following Sections discuss each type of measure in further detail and set out any quantified energy savings found during the literature review[39].

39 We have provided additional information e.g. around the background to behavioural measures where requested by Defra in response to the interim report.

3. INFORMATION MEASURES: BACKGROUND INFORMATION

Inducing behavioural change is not a straightforward process. Informing people about climate change and providing them with mobilising information alone is not enough to change behaviour. The process of promoting energy efficient behaviour and technology uptake may require a degree of persuasion to encourage the end-user to modify what they do. This section introduces some background on changing attitudes and behaviour, before exploring current and future options for information provision.

3.1 Influencing behaviour: background on the principles

There is an large volume of literature relating to the modelling and influencing of human behaviour, ranging from cognitive and social psychology through to marketing and advertising methodologies. To date, the dominant narrative in domestic energy policy has been that of consumers in ‘knowledge deficit’. This is the concept that, if a consumer’s energy use was better understood, consumers would adopt more efficient behaviour and chose more efficient products, closing the ‘energy efficiency gap’ (between what is cost effective and what is actually done).

This narrative relies on the assumption of the ‘rational consumer’ who changes behaviour through choice, based on understanding and attitude. However, the notion of ‘rational choice’ has long been challenged. Various alternative models and some key issues have been raised, including those ideas highlighted below.

“*One of the messages that flows from this analysis is that consumers are a long way from being willing actors in the consumption process, capable of exercising either rational or irrational choice in the satisfaction of their own needs and desires. More often they find themselves ‘locked in’ to unsustainable patterns of consumption, either by social norms which lie beyond individual control, or else by the constraints of the institutional context within which individual choice is negotiated*.” (Jackson, 2005)

The literature does not discount the possibility for ‘rational choice’ but other factors are also argued to be strong determinants of behaviour, namely:

- **Habits:** Individuals often act instinctively or out of habit, rather than necessarily being driven by particular events or circumstances. Habits are useful in that they avoid the need for a full ‘cognitive deliberation’ over one’s everyday actions. Even when an individual decides that they want to change what they do, for old habits to be broken, repeated ‘presence of mind’ is required before the new behaviour itself becomes routine[40].

- **Social norms:** Weakly-held attitudes do not motivate changes in behaviour and ambiguity of attitudes in a social group can leave individuals with an ambiguous attitude. This is a result of a fact that that common attitudes help bind people together and also help to change individuals’ attitudes. Common attitudes are likely to change if the social norms change (Hilgard et al., 1996). This demonstrates an additional value of community-based energy efficiency activities which whilst educating will also have a normalising effect.

40 By bringing the intended change to mind, a change in the nature and frequency of energy consumption feedback e.g. from billing to visual display unit in home may help shape a change in habits.

- **Authority:** As well as adhering to social norms of attitude and behaviour, individuals have a strong tendency to behave in compliance with authority. This is because it is "*a necessary requirement for communal life*" that "*has probably been built into our species by evolution*" (Jackson, 2005). Experiments have proven our apparently innate tendency to comply with the demands of authority.

  - Moreover, it has also been shown that attitudes change in response to new behaviour, since the mind has to resolve conflict between attitude and behaviour (Cognitive dissonance theory). An example of this is perhaps the 'weakly enforced' use of authority to promote recycling with green bins which has lead to a positive change in attitudes about recycling. (The visible activities of neighbours also reinforced this as social norm)

- **Influential minorities:** Significant societal changes can be brought about by individuals who manage to persuade the group to adopt different attitudes and behaviour (Jackson, 2005)[41]

- **Symbolic and emotional factors**: Advertising culture has long demonstrated the power of symbolism and emotions in affecting behaviour.

3.2 Influencing behaviour through persuasion

Persuasion can be divided into three broad categories: response shaping, response reinforcing and response changing (Jowett and O'Donnell, 1986).

- Response shaping: is a process where incremental changes in attitude or behaviour are reinforced through reward, in a teaching-like process.

- Response reinforcing: is where existing attitudes or behaviour are reinforced to obtain an increased response in attitude or behaviour.

- Response changing: the category that it can be most difficult to deliver, refers to changing attitudes and behaviour.

The common goal of energy efficiency information is to change behaviour. In order to be effective, individual communication events must serve a specific objective, i.e. they must shape, reinforce, or change a specific attitude or behaviour.

Whichever category of persuasion a measure is designed to achieve, it needs to somehow tap into the pre-existing patterns of understanding of the audience. To do this, the audience must be understood (in terms of its existing beliefs, values, attitudes and behaviour, as well as the norms of their social group).

The persuader also needs to relate the required behavioural change to something the audience already believes in. This concept is known as 'anchoring'; where a premise is attached to something already accepted by the audience and is used to tie down (or to anchor) new attitudes or behaviour (Jowett and O'Donnell, 1986).

41 'Minorities can move majorities towards their point of view if they present a consistent position without appearing rigid, dogmatic or arrogant. Such minorities are perceived to be more confident and, occasionally more competent than the majority. Minorities are also more effective if they argue a position that is consistent with the developing social norms of the larger society.' (Hilgard et al., 1996)

3.2.1 Perceptions of energy efficiency benefits

Even if climate change is not seen as a sufficient driver to change attitudes, energy efficiency has a number of other benefits, which are commonly used by business to justify and drive such activities. In the domestic sector the benefits are not always well understood, and there may be a gap between the actuality and individuals' perceptions.

- **Saving money:** this benefit is universally endorsed, since it is tangible, appeals to people's self-interest and is common to all energy efficiency measures. However, it can take a long time for the initial investment to pay for itself and the savings are often difficult to quantify or too small to influence purchases, particularly those involving a high initial capital outlay (Garmeson, 2002);

- **Improved comfort:** this may be *"a tangible benefit, although the reassurance that energy efficiency does not require people to make sacrifices in their lifestyle may be still more important"* (Garmeson, 2002);

- **Avoiding waste and the environment:** this benefit is *"less widely mentioned and more commonly associated with energy saving than energy efficiency. It is perceived as a moral obligation, particularly among older people and the struggling poor, with its roots in the way in which people were brought up. It has environmental connotations but in this context is more commonly linked with saving money ['waste not, want not']."* (Garmeson, 2002).

3.3 Influencing behaviour: what types of information encourage change?

We noted four kinds of information above (Section 2.2.2). Given the drivers for change identified above, we consider it to be unlikely that increased awareness and understanding of climate change will have an impact on behaviour on its own. Information that raises awareness of the impact of individual/households on climate change may have something more of an impact, but only if combined with information about why that impact occurs and what can be done to reduce it (mobilising information[42]). This is considered in a more detail below.

3.3.1 Climate change

The vast majority of people are aware of the concept of climate change and over half of those surveyed consider that climate change is a result of mainly human behaviour. However, despite this, a far smaller number of people have changed their behaviour (or would be prepared to change their behaviour) to reduce their personal impact (Defra, 2008b)[43]. This demonstrates a gap between understanding and behaviour; it exposes the real challenge of inducing behavioural change.

3.3.2 Awareness raising

With this in mind, encouraging people to change their energy consuming behaviour requires increased awareness and understanding across several areas, including:

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42 'Mobilising information' is information which allows people to act. It might be suggestions about where to go, what to do or whom to contact (Lemert et al., 1975). Once a customer wants to change their energy consuming behaviour, however motivated, they then may require further information to allow them to act.

43 e.g. only around 15% of people use less electricity or would consider using less electricity

- **Awareness of personal contribution to the problem.** This can be achieved by shaping attitudes towards climate change and energy efficiency measures.

  - This may involve identification of the main emission sources (from individuals or households) and quantifying emissions from them.

  - This can also involve providing mobilising information that communicates the relative effect of different measures.

- **Awareness of how to reduce emissions.** 'Mobilising' information can help energy consumers to act on their new knowledge of climate change and energy efficiency measures. This kind of information would include what to do or what to buy, or actions/ appliances to avoid.

Treating these as separate types of information to be provided allows different approaches to be used with different social groups, as opposed to trying to change understanding, attitude and behaviour en mass.

3.4 Influencing behaviour: how can that information be presented effectively?

The way that any type of information is provided will affect how great an impact it has on energy use.

3.4.1 Information provider

Who provides information may have a significant impact on the impact it has on the recipient. For instance, customers may be more distrustful of information provided by a commercial company than a public body (illustrated in the trial described below).

Figure 4 Impact of information provider

An electricity company and its incentive programme were presented to consumers using three alternative letter formats:

- from the company itself;

- from the company but mentioning that the local authority was co-sponsoring the programme,

- and finally from the local authority itself, on their note paper, written by the chairman of the Board of Commissioners.

In each case, the information provided about the incentive scheme was identical, however there was a 25% difference between the impact of the most effective (letter from local authority) and the least effective (letter from the company) intervention of consumer response. (Devine-Wright, H. and Devine-Wright, P. 2004).

3.4.2 Audience specific 'anchors'

It is difficult to effectively target the whole population with a single type of information campaign. Audience specific 'anchors' are needed to 'bind' persuasion and change attitudes, e.g. one person may be most likely to respond to the need to reduce their impact on the environment, another may be more likely to be driven by financial motives. Depending on the energy efficiency measure being promoted and the target audience, different anchors might be used e.g. energy costs and cost benefits of energy efficiency, appeals to frugality, kudos, technical advantages, maintenance benefits, lifestyle, or concern about climate change.

Much work has been carried out by Defra to better understand the different environmental attitudes and resulting behaviour of different types of people. Under its work programme on Sustainable Consumption and Production (SCP), Defra has developed a framework for pro-environmental behaviours [44] which summarises evidence on consumer behaviour and is designed to support policy development and implementation in Defra, other Government departments and externally.

The framework includes an environmental segmentation model that divides the public into seven clusters, each sharing a distinct set of attitudes and beliefs towards the environment. Outputs from the segmentation model will be useful in developing more audience specific information campaigns.

3.4.3 Energy consumption feedback

The vast majority of people in the UK have little idea of how much energy they are consuming and are unable to attribute consumption to individual appliances or their behaviour. This contrasts with water which, despite being unmetered for the majority of domestic customers in the UK, is often conserved as people can literally see the water running down the plug hole (TACMA Interview).

Currently most consumers only receive feedback on their energy consumption once every three months. Whilst suppliers have made efforts to improve the regularity and frequency of meter readings, some households still receive estimated bills and so it can be longer than three months between actual information provision.

Estimated bills may only have a small margin of error; however, any lack of accuracy may hide the impact of behavioural change. In addition, if households perceive estimated bills to be ‘wrong’ then they may distrust the information provided [45] or be less prepared to use it as an indicator of progress in energy saving[46].

Even if consumers are provided with an accurate bill four times a year this may be too infrequent to impact on behaviour as it is hard to see the immediate impact of any changes made. Historically it has not always been straightforward to understand energy use from the bill, since the focus is on the price rather than energy consumption[47].

Changes in consumption can also be masked by changes in energy price. This is particularly important during periods of rapid energy price increases where any reductions in consumption can be easily hidden (RWE nPower Interview). In addition, the bill can arrive some time after a price change and therefore consumers do not have the information required to react to it.

The move to direct debit may reduce feedback yet further; anecdotal evidence suggests that many customers do not check how much their bill is when it automatically leaves their bank account.

44 http://www.defra.gov.uk/evidence/social/behaviour/index.htm
45 Particularly if the bill is perceived to be an over-estimate.
46 Based on experience of the authors of this report
47 Based on experience of the authors of this report

Methods and types of feedback provision

Feedback on energy consumption can be provided in a number of ways from a simple paper utility bill to a colour coded glowing visual display in the home. There are also different types of feedback that are not typically provided to UK consumers but might help change behaviour:

- **Historical feedback:** where a user's consumption is compared to past consumption. This may be normalised against outdoor temperature.
- **Comparative feedback:** where a consumer's consumption is compared against the consumption of others. Consumption could be compared to other households of a similar size and occupancy (using benchmark data) or against peers (e.g. on a community website)
- **Normative or disaggregated feedback: t**his gives consumers information on the consumption of different appliances in the home. This can be provided using estimates of typical break-downs of end energy use, or can be estimated by observing real time energy data on a visual display unit or can be more accurately measured using either intrusive or non-intrusive monitoring (see section 4.2.2 below).

Impact of feedback provision

In our view the impact the feedback will have will depend on many factors including:

- the type of information presented (whether it is historical, comparative or disaggregated),
- the way it is presented (whether it is on a website that the user has to actively go to), and
- the frequency the information is given (whether or not the consumer sees consumption in real-time or only every few months).

Different types of feedback may lead to different types of behavioural change e.g. the provision of real-time consumption data may lead to people switching off appliances when not in use or reducing the use of energy intensive appliances. The provision of historical or comparative feedback may motivate some consumers to reduce non essential electricity use or turn down the thermostat.

The provision of comparative feedback could be accompanied by advice from a third party on long-term measures to reduce total consumption e.g. if gas use was high a supplier might suggest increasing insulation. Demand data collected by a smart meter could be used by a third party e.g. an energy supplier or Energy Service Company (ESCO) to tailor advice or conduct a 'remote energy audit'. In order to facilitate this we think that it is important for consumers to have easy access to the data from their smart meter and the meter operators[48] should be obliged to provide data at low or no cost to a third party.

Data resolution

In Great Britain, the balancing and settlement of electricity on the wholesale market, and so for retail, is on a half hourly basis. As a result, half-hourly meters

48 Which may be suppliers but the responsible organisation will depend on the model used for Smart Meter implementation.

would typically record energy consumption (in kWh), accumulated in half-hourly registers[49]. This provides sufficient resolution to provide some advice on energy and carbon saving opportunities. However, for some purposes, like analysing the suitability of carbon reduction options such as micro-generation, a higher resolution of raw data could be more effective. In principle it would be possible to record this too, for example using a memory stick.

High resolution data capture (in the order of seconds not minutes[50]) and the recording of reactive power (VARs) could allow remote analysis of appliance activity, for example:

- Excessive fridge cycling indicating leak or fault.
- Excessive VAR consumption of washing machine indicating fault.
- High base load indicating cost of stand-by and computers left on.

This kind of data could be analysed visually by an adviser, or automatically with software. This activity could be conducted by a third party or the customer themselves if equipped with appropriate software tools. If meter technology allowed individuals to access raw data, with say a memory stick, then it could encourage innovation in software tools to analyse demand.

49 Even though the meter constantly monitors energy flow
50 In this respect some ‘clip-on’ technologies, e.g. the Wattson, are leading the way with resolution down to 3 seconds.

4. INFORMATION MEASURES: EVIDENCE OF SAVINGS

A large number of generic awareness raising programs provide information across some or all of the areas in the last Section. In the text below we provide some examples of the types of initiative underway, and where available, present evidence of their impacts.

4.1 Awareness of impact of individual/ households

4.1.1 General education

Interactive websites

The 'Act on CO_2 calculator' (part of the Government's Climate Change Communications Initiative) aims to: raise awareness of climate change; quantify an individual's carbon footprint, and provides tips on reduction techniques. This website incorporates aspects of all three information types.

Several other websites seek to inform the domestic sector how to reduce carbon, including:

- The BBC Bloom website;
- Big Green Switch;
- Energy suppliers' on-line calculators (see energy audits below).

A number of companies also have their own websites for employees or their customers. These commonly contain similar information, plus facts about what the organisation is doing to reduce its own carbon impact. For example, BSkyB has an interactive website for their staff which gives them rewards for pro-environmental behaviour and has a lift sharing booking system[51].

Interactive websites may increase participation in energy efficient behaviour and purchases, but for the reasons previously described will mainly attract individuals that are already motivated. This may mean that the information on websites may only reach motivated individual or the 'positive greens' under the Defra segmentation model, which only represent 18% of the population (Defra, 2008a).

Projects such as Green Streets (see Figure 5 suggest that even motivated individuals may save more energy when they have better information and are in competition with peers.

Support and guidance

The Energy Saving Trust (EST) is the main provider of advice to the domestic sector on energy efficiency and microgeneration technologies, through a number of initiatives including:

- publicity campaigns,
- a website with a number of publications and guides,

51 http://www.jointhebiggerpicture.com/EnvironmentHome/Environment/WhatsSkydoing/EnablingEmployees.aspx

- a telephone helpline,
- administration of a number of grant programmes e.g. the Low Carbon Buildings Programme (LCBP),
- advice to householders through working with communities, local authorities and housing associations,
- community projects and competitions for example the Green Neighbourhoods scheme[52],
- 'one stop shops' for advice, for instance:
  - The network of Energy Saving Trust advice centres provides free expert advice about domestic energy efficiency. Set up in 1996, there are 21 Energy Saving Trust advice centres across the UK.
  - EST Green Homes Service (currently under development) will provide a single place where people can access information, advice and support on energy saving, domestic renewables, personal transport, reducing waste and saving waters.

EST also undertakes research into energy efficiency and microgeneration in the domestic sector that aims to increase consumer acceptance of more expensive measures. For example, we understand that EST is currently undertaking field trials of solid wall insulation, advanced heating controls and Light Emitting Diodes (LEDs) using funding from the Environmental Transformation Fund (ETF). EST is also leading microgeneration monitoring trials for micro-wind and heat pumps (EST, November 2008).

Effectiveness of EST

The Energy Saving Trust estimates the carbon savings it has achieved in the domestic sector using results from a consumer survey. Carbon savings include savings from consumer advice on renewables but EST does not break down the savings further when assessing the impact of its activities (EST Annual Report). The Energy Saving Trust only ascribes behavioural savings a lifetime of one year.

The savings associated with general energy efficiency advice are difficult to quantify. In order for the energy efficiency advice provided by the EST to deliver energy savings, it relies on householders taking action in response. While the EST surveys householders "*getting a true picture of householder behaviour is difficult, not least because people generally claim to be greener than they really are*". This is "*something the Trust endeavour to adjust for*" (NAO, 2008).

52 The Green Neighbourhoods project aims to give a 'green makeover' to up to 100 neighbourhoods in England, with the aim of reducing their carbon footprints by more than 60 per cent. Local alliances between householders, community groups, local authorities, energy suppliers, private companies, and banks will bid for funding which will be used to help transform the environmental performance of a street or local area. The initiative will focus on hard to treat homes such as Victorian terraces and poorly insulated tower blocks which often have solid walls or no loft space (Source: http://www.defra.gov.uk/environment/climatechange/uk/household/neighbourhood/index.htm).

The EEACs claim to have advised over 7 million customers, saving 12 million tonnes of carbon dioxide (CO_2) over the lifetime of their actions. EST has undertaken additional evaluation work of the impact of the scheme and we understand that it is now in a position to quantify savings from behavioural change.

4.1.2 Better billing

As things stand, meters are required to be read every two years (minimum requirement), although most suppliers continue to seek to read quarterly. Most suppliers allow customers to phone or email meter readings as an alternative, but this does not guarantee accurate billing of a sufficient frequency to support behavioural change (see discussion above). UK suppliers began in October 2005 to disclose the generation fuel mix of electricity supplied to customers.

There is consequently considerable scope for domestic consumers to be provided with more information on their energy consumption via their existing energy bills. A number of options exist including:

- more frequent bills;
- frequent bills based on readings plus historical feedback;
- frequent bills based on readings plus comparative/normative feedback;
- frequent bills plus disaggregated feedback;
- frequent bills plus detailed annual or quarterly energy reports.

The way in which any information is presented is also key to supporting behavioural change. Information needs to be readily understandable and easy to compare (between suppliers and on previous years) to be effective.

Studies on the energy savings resulting from informative billing indicate a range of 0-12% (see table below for a summary of the relevant studies).

Although some argue that the increased awareness caused by better billing could result in significant additional energy savings, this is not guaranteed. For instance, there is the risk that people fail to even open their bills (especially if sent electronically and paid via direct debit).

The use of smart meters (see below) would significantly reduce the cost of meter reading for suppliers and improve accuracy. However, it would only improve the information received by the household if the meter is located in a visible position (rather than hidden in a box or cupboard under the stairs), and if the information it provides is displayed in a meaningful way in a prominent position. To be able to use the information, the householder is dependent on the meter operator providing them with useful data that will help them to reduce their energy use.

Table 9 Summaries of studies considering different informative billing strategies

Case study	Headline results	Detailed results	Sources
Informative billing, Norway	Informative billing shows persistence of savings over several years Norwegian Government made quarterly informative billing mandatory	Savings average 10% - for customers of Oslo Energi: they received bills based on electricity meter readings at 60-day intervals (rather than the usual single meter reading a year and four bills, three of which were estimates). Savings average rose to 12% - when frequent bills were supplemented by feedback comparing consumption with the same period of previous year and all periods in between. Advice tips did not appear to add to the impact of the frequent bills and feedback. Customers were interested in continuing with the new billing system at project close. Single most effective change was from quarterly estimated bills (only one meter reading per year) to bimonthly, accurate bills. Identified causal chain: Increased feedback – increase in awareness or knowledge – changes in energy-use behaviour – decrease in consumption.	Original study Wilhite and Ling, 1995; Reported in Darby 2006
Self-read meters, readings sent by consumers to utility, Stavanger – Norway (Plus: consumers were helped to understand their new informative energy bills by a brochure in simple language)	Increased awareness and understanding of billing information Reduced energy consumption	Increases of 15-20% in claimed awareness and understanding of billing information resulted over a period of just over a year. Consumer reaction to this project was also very positive. Both studies involved a representative cross-section of households, with roughly 25% using all-electric space heating and 50% some electric space heating. 3 years after start of Stavanger trial, customers in trial were consuming 8% less electricity than general population in the area who were receiving quarterly bills mostly based on estimates. Their consumption had fallen by 4% compared with that before the new bills were introduced, while that of the control population had risen by 4%. Norwegian findings – relevant to a discussion of Automated Meter Reading.	Original study Wilhite, 1997; reported in Darby 2006

Case study	Headline results	Detailed results	Sources
Billing review, of Nordic countries	Longer trials and more information provided regularly to customer gives more persistent effects	Regular reminders of consumption can be a continuing influence, as well as reducing consumption in the first instance	Henryson et al., 2000

Other sources reiterate results from the above studies: van Houwelingen and van Raaij (reported in Darby, 2006) found that:

- Savings fell off when the gas consumption display monitor was removed from homes;
- Persistent feedback promotes persistent conservation behaviour and also has implications for the development of technology; and
- The regulatory requirement for monthly, accurate bills in Sweden drove the move to smarter (and remote) metering.

4.2 Consumption data

4.2.1 Total energy consumption raw data

The standard gas or electricity meter can be used to give a very basic form of energy consumption feedback, based on cumulative use and cost. However the meter is often out of sight and some bills are based on a mix of actual and estimated readings.

However there have been examples of initiatives using data from simple meters to reduce consumption. An advice programme run by West Lothian District Council which asked clients to phone in their meter readings over a number of weeks reported savings in the region of 10% after three months from behavioural change alone and mostly from fuel-poor clients (Darby, 2006).

4.2.2 Appliance level consumption data

Visual display units (VDUs) showing real time electricity consumption data can provide information on total consumption and cost in real time. They can also give crude feedback on the contribution individual appliances make to total consumption, provided the signal from the meter shows up on the display spontaneously. This may help to identify stand-by consumption and energy intensive appliances. Most real time displays (RTDs) show cumulative data, for example by day, week or month, as well as real-time information, and some can download data onto a PC for more detailed analysis. Portable end-use monitor plugs, also on sale in the UK, serve a similar function for one appliance at a time (Darby, 2006).

There is little evidence that detailed information at the appliance level results in additional savings, but it may result in reduced use of particular appliances that are very energy intensive or help to drive the replacement of appliances with energy efficient models.

There are two types of higher resolution metering which aid a better understanding of the contribution an individual appliance makes to a building's overall energy consumption:

- **Intrusive monitoring:** uses sub-metering. It might be too expensive for everyday use by householders (due to the large number of meters and sensors involved) but it could be a useful tool to better understand actual domestic energy use. It could also help to fill the large data gap that currently exists. A number of trials are underway to try to gather appliance level data (Digital Living Interview) which should provide vital information for policy makers, researchers and grid operators.

- **Non-intrusive monitoring:** analysis of overall demand profile to see consumption from different appliances based on their power signature[53]. This could enable remote energy audits to be undertaken where household use is broken down and assessed remotely or by the householder themselves on their own PC.

Work is currently underway to explore how monitoring of domestic energy use could be improved. The European funded research project, Digital Environment Home Energy Management System, aims to monitor consumption at an appliance level and is looking at the possibility of connecting appliances to a management system.

4.2.3 Presentation of interpreted energy consumption data

Interpreted data can be sent to a meter or to a remote third party and then communicated to the individual in a range of different ways, including on a display unit in the home, on websites or on bills, described below.

Display of information by technology in home

Real time digital display

Real time energy consumption on a digital display is a simple, cost-effective way of displaying information. If the first few months of interest lead to long term behavioural change some long term savings may be achieved. However, the data may not be meaningful to some people and can be easily ignored over time as interest may wane over the medium- to long-term. Whilst some models can collect historical data some clip-on systems do not which means that trends over time cannot be observed[54].

Real time displays on the market

There is a wide range of real time display types on the market and the majority show only electricity consumption primarily because there are many more behaviours that can be changed in real-time to save electricity.

- **Simple** displays only show total electricity consumption over a specified timeframe and cost in real time, although many also store cumulative data over days, weeks or months.

- **More sophisticated** displays could present energy consumption of multiple appliances and disaggregate total electricity consumption.

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53 Power and phase against time; heating purely resistive, motors reactive etc. Currently at a research stage but several approaches possible.

54 Real time displays are beginning to store more historical data.

- **Top end** displays allow for any number of appliances to be monitored and displayed[55], historic and peer group consumption data could be compared to the actual consumption and the display could even control the appliances[56].

The degree of sophistication will impact on the savings achievable and the cost involved. Savings associated with relatively simple displays are around 10% according to Darby (2006) who reviewed a number of case studies. Sophisticated displays in connection to a smart meter could deliver up to as much as 20-25% savings (Green Energy Options Interview).

More evidence on potential savings from increased feedback from VDUs can be expected from the Energy Demand Research Project, which will conclude in 2010.

Gas consumption information

Some display units can give users basic information on gas consumption. However as most of the heat in a domestic building is used for space heating and most installed boilers switch on and off to maintain the temperature, real time feedback of gas meters is of little practical value. In future, displays could be linked to existing meters (via retrofit) or to new smart meters to show total gas consumption and cost.

Gas displays can usefully provide information on the time the system is working, the purpose for which heat has been produced (space heating, hot water etc.) and how many units of gas have been consumed (Green Energy Options Interview). As data on gas is historic, it may influence people to invest in insulation (particularly if compared against other households or best practice benchmarks) or to change the thermostat settings/ timer for future use, but cannot have an immediate impact. No evidence to quantify how a gas monitor could influence demand has been identified.

Other display technologies

Some systems use colour to give indication of consumption, e.g. red is high, green is low, as it may be more easily interpreted by the user. Other systems use sound or flashing lights to alert householders when the load goes over a threshold (which can be determined by the householder). Ambient signals such as these may help to sustain interest, although some people may find them intrusive.

In terms of evidence, a flashing light was used to alert a sample of American householders that the outdoor temperature had dropped below 68°F(20°C) and it was time to turn off the air-conditioning and open windows for cooling instead. This gave savings of 16% over a three-week period (Seligman et al. 1978).

Websites

Data can either be manually entered, downloaded from a RTD onto a PC and sent or sent directly by a smart meter system to a website or other third party for analysis.

A number of trials have found that the presentation of feedback via interactive internet sites or TVs in the home can be effective:

55 However cost may limit the number of appliances that can be monitored in practise.
56 For example, it could switch the washing machine one when the photovoltaic system produces electricity (Caiger-Smith September 2008).

- Benders et al. (2005) report energy savings of 8.5% from the use of an interactive web page by 137 Dutch households. It helped analyse consumption and establish relevant conservation measures. Money saved by using less energy was invested in efficiency measures, contributing to the persistence of the savings.

- Brandon and Lewis, in one of the few British feedback trials, found interactive display via a PC the most promising method (1999) (Darby, 2007).

The problem of sustaining interest in software/ community websites in the medium- to long-term may be greater than for visual display units that are in a prominent position in the home (with the community approach, users would need to actively go to the website to view their consumption).

Community websites where people compete with each other to reduce their energy consumption are also becoming more popular. This may increase peer pressure and help to sustain motivation levels in the medium-long term (see discussion of social norms above). The interim report from IPPR on the Green Streets project (see box below) suggests that competition between communities can help to reduce emissions.

Figure 5 Green Streets Competition

Green Streets is a year-long competition run by British Gas to reduce energy use and emissions in 64 households - 8 each from a street in 8 cities (Birmingham, Cardiff, Edinburgh, Leeds, London, Manchester, Southampton and Plymouth).

Participants were provided with up to £30,000 to spend on energy efficient and microgeneration equipment including insulation, low energy lighting, A++ appliances, high efficiency condensing boilers and PV. Each street was supported by a dedicated energy efficiency advisor. The street that achieves the largest carbon reductions can win prize of £50,000 to spend on a community project.

High level findings from Green Streets competition:

- led to large (20%+, 30% in Leeds) and so far sustained average energy and carbon savings in most cities;

- initial analysis of the data suggests that behavioural change is playing a big role alongside installed measures;

- the back up from the energy efficiency experts and BG more widely was important;
- the competition element has been important for motivating behaviour change.

Recommendations:

- develop a dedicated network of independent neighbourhood-based energy advisers develop finance packages for energy saving measures.

- put in place competitions for saving energy at street, neighbourhood, city and national levels.

A nine-month trial of interactive online displays was conducted in Japan showing historic consumption, daily and 10-daily costs, living room temperatures and comparisons with other homes. The trial, which cost around $5000 per display, gave electricity savings of 18% and gas savings of 9% compared with control groups, for the 10 householders who took part in the trial (Ueno et al. 2005). However, the savings cannot be considered to be representative given the small sample size. The high cost of the display also makes it unlikely to be cost effective.

Criticism of comparative feedback relates to problems with the choice of comparison group and concern that people will only act if they consume more than average and will reduce motivation in those that consume less than average (Darby, 2006).

However the popularity and effectiveness of comparative feedback may depend on who is giving the feedback. People may be less likely to respond to comparative feedback (and be distrustful of the comparisons made) if it is given to them by suppliers than if the feedback was provided by a voluntary scheme such as a community website (see section 3.4.1). The increased use of networking sites (e.g. Facebook, MySpace etc.) creates a much greater opportunity for increased comparative feedback and competition.

The use of competitions such as the Green Streets may help to create ongoing motivation for those whose consumption is below average. This highlights the need to ensure that information e.g. from a smart meters could be made available to other actors than suppliers (at the customers discretion).

Role of Smart Meters

Smart meters can help to increase feedback to consumers if they can either send useful and informative data to a visual display unit in the home and/or they can send data to a home PC, mobile or a remote third party such as a community website[57].

The Energy White Paper (DTI, 2007) states that smart meters with visual display units should be installed across all households in the medium term "*Our expectation is that, within the next 10 years, all domestic energy customers will have smart meters with visual displays of real-time information that allow communication between the meter, the energy supplier and the customer. The display will provide customers with readily accessible information about their energy usage. The Government will work with suppliers, Ofgem and other interested parties in these developments, including through our Energy Demand Research Project. We expect suppliers to roll out smart meters when it is cost effective to do so and within the timescales we have set. Government believes displays should be provided with smart meters in the longer-term, and has considered their role in the shorter-term. The Government will consult on the implementation of these proposals in the context of our ambition to see a roll out of smart meters within ten years. The provision of real-time displays with smart meters has the potential to transform how households manage their energy use. Our objective is to see households have access to this new technology as soon as possible to enable them to control their emissions. It is possible that some of our metering and billing proposals set out in this White Paper will be taken forward in the context of the implementation of the Energy Services Directive.*"

The provision of smart meters with a real-time display enables consumers to access more information about energy use and cost. In addition, it could provide

57 Enabling better energy consumption feedback to consumers (when installed with a VDU or if data is sent to website) is only one of several benefits associated with smart meters. Other benefits include: providing access to time of use tariffs and the resulting potential to load shift. They would also be useful for demand forecasting and, in the case of microgeneration, for production forecasting which National Grid undertakes for Ofgem (National Grid, September 2008).

information to energy suppliers. This could enable targeted energy efficiency advice/ products and other demand side management techniques e.g. the provision of flexible tariffs.

Smart meters could help provide consumers with better feedback whether in the form of more accurate paper bills, in the home (if a visual display unit was installed) or remotely (e.g. on a personal, supplier, community or networking website). Smart meters allow for all types of feedback to be given to consumers:

- **Historical:** data can be sent either to a personal website to allow for users to observe long-term trends or it could be sent to third party who could use it to conduct a remote energy audit.

- **Comparative:** data can be sent to a community website or networking site which the householder can log onto.

- **Disaggregated data:** the provision of a visual display unit would allow for real time energy consumption to be observed giving an indication of the load or cost of running different appliances.

However, the data collected by the smart meter needs to be collected, manipulated and effectively communicated in order for there to be increased feedback.

Estimates of savings resulting from smart meters with real time displays vary. Ofgem's cost-benefit analysis assumed a 1% energy saving realised from smart meters, which is at the lower end of the saving (1-3%) reported in Owen and Ward (2006). Other studies have been more optimistic. For instance, Energywatch gives a range of energy saving of 3.5-7% (BERR, 2008a).

BERR[58] split consumers into three categories (enthusiasts, followers and laggards), and then applied different saving rates to each of them. It assumed that the following gross annual reductions in demand would take place as a result of improved feedback on the use and cost of energy: 2.8% for electricity; 2% for gas credit and 0.5% for gas[59].

These estimates only consider the potential saving at the meter resulting from behavioural change from increased feedback. They do not consider the additional indirect savings resulting from the other benefits associated with smart meters. Further work is required to better understand the total financial and carbon benefits associated with different smart meter systems.

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58 Impact Assessment of Smart Metering Roll Out for Domestic Consumers and Small Businesses

59 BERR notes that none of the previous studies appear to have taken into account the energy requirements of the metering, display and communications equipment, which should be included in order to provide net energy savings. Based on discussions with meter specialists, BERR estimates that the additional smart equipment costs could be 1.25w/h for the meter including communications and 0.6w/h for the RTD (BERR, 2008a). Assuming a power consumption of 1.25W for the meter and 0.6W for the RTD this would equate to an annual consumption of 11kWh and 5kWh respectively.

4.3 Efficiency of consumer goods and buildings

4.3.1 Energy labels

Energy labels enable customers to make more informed choices. The labelling of goods under the Energy Labelling Directive provides consumers with information on the rating of the appliance in terms of energy efficiency at the point of purchase.

However the label does not cover a number of goods such as electronic equipment which are increasing in number per household. There is also documented evidence that rating schemes can limit perceptions of what is available e.g. with A being perceived as a 'top' rating and may hinder innovation within the manufacturing base (see section 8.5.2 for a full analysis).

Energy Star Programme

The ENERGY STAR programme is an energy labelling initiative run by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DoE). Product categories include: home appliances like freezers, battery chargers; heating and cooling like ceiling fan, insulation, air-source heat pumps; home envelope (insulation, air sealing) & home electronics. Products are assessed against the following criteria:

- Significant energy savings will be realised on a national basis.
- Product energy consumption and performance can be measured and verified with testing.
- Product performance will be maintained or enhanced.
- Purchasers of the product will recover any cost difference within a reasonable time period.
- Specifications do not unjustly favour any one technology.
- Labelling will effectively differentiate products to purchasers.

Unlike the EU labelling system appliances are not rated.

4.3.2 Procurement advice

Instead of an energy label, some bodies have developed lists of appliances that they deem to be energy efficient. For instance, the EST runs a voluntary domestic product labelling scheme, Energy Saving Recommended (ESR). ESR covers seven sectors and 30 individual product groups with standards that are regularly reviewed. At the time of writing, the ESR covered in excess of 3,200 certified products with over 220 registered companies (EST, November 2008).

The ESR aims to endorse a maximum of the top 20% of the market in any one product category, thereby acting as a 'quality mark' for lower energy consumption. Consequently it is both dynamic and flexible and can therefore respond to market developments and innovation more quickly than other labels such as Energy Star or the EU A-G Energy Label. The ESR is underpinned by additional activity e.g. development of retailer's buyers guides, training of in-store staff and marketing activity (which is targeted through EST's consumer segmentation model) (EST, November 2008).

There is significant additional potential for low carbon products and designs; the supply chain is well-placed to assist in the adoption of these (see section 11.8.6 on supply side barriers).

4.4 Information on reducing emissions

4.4.1 Energy audits

Home energy audits can be an effective way to identify cost-effective energy saving opportunities. They provide vital baseline information on the 'energy capital' of a dwelling as well as giving guidance on how to improve it. They can also include behavioural advice on the best way to operate buildings and appliances.

Audits may be:

- undertaken by a surveyor on the householder's initiative;
- undertaken as part of a mortgage or other mandatory survey;
- carried out on an informal basis by the consumer using freely available software.

A series of audits can give a stream of feedback, guiding a motivated consumer towards a target for reductions to consumption. Given their cost, more formal audits are likely to be infrequent, but can still indicate degrees of progress.

For instance, a community programme involving home energy audits for 1,600 households followed by subsidised retrofitting was estimated to have achieved a reduction of 20% in peak demand*. "It could be argued that this was solely due to physical measures, but the strong emphasis on participation and learning suggests a contribution from inadvertent feedback." (Darby, 2002)*

Only a small number of the studies identified in the literature review estimated the energy and carbon savings resulting from energy audits. For instance, the Green Doctor Project in Leicester involved the provision of free, one-off visits to low-income households in priority wards in Leicester city[60]. Between 2003 and 2006, 794 home visits were carried out saving £9,971 per year in energy costs and an estimated 68tC per year.

The London Development Agency (LDA) has also launched a green concierge service which offers London households a home energy audit and ongoing advice for a year for £199. Homes Concierge service staff use software to calculate energy wastage, then recommend measures that can reduce energy consumption. The Concierge Service undertakes research for clients, recommend contractors, point householders towards discounted energy-saving equipment, and can help manage home improvement work[61].

4.5 Actions resulting from behavioural change

For the reasons described earlier, a display device or improved bill is unlikely to change attitudes or deliver significant, sustained behaviour change on its own. However, it can provide a source of mobilising information in order for the

60 http://www.groundwork.org.uk/upload/news/29_document1.pdf
61 http://www.londonclimatechange.co.uk/greenhomes/green-concierge-service/

consumer to act and may also help to shape and reinforce attitudes. This can impact on behaviour though improved understanding and reward (financial, achievement or environment). Moreover, these benefits can then spread through 'influential minorities', social norms and benefits of 'learning by doing' of individuals benefits are understood by the consumer.

Some of the energy and carbon activity that may result from information provision are illustrated below:

- remembering to turn off lights and switch off appliances at the socket;
- fully loading clothes and dish washing machine;
- choosing deferral option on appliances such as washing machines;*
- choosing low energy options on appliances for example 30°C wash.
- choosing an interruptible tariff or changing to a supplier that offers a time of use tariff;*
- buying efficient appliances;
- relocating fridge or freezer to a colder room;
- buying less non-essential appliances;
- disposing of non-essential appliances;
- choosing activities that do not use energy e.g. reading a book;
- investing in microgeneration then synchronising appliance use with microgeneration;*
- explaining benefits to neighbours;
- setting up a local energy reduction group as 'local leader'.

* These actions may not reduce absolute energy consumption, but may help to reduce peak electricity consumption which can have carbon benefits (see section 10 on supply side impacts).

5. TECHNOLOGICAL TOOLS: EVIDENCE OF SAVINGS

Based on the literature review undertaken, there is a lack of evidence on energy and carbon savings associated with the technological measures discussed below. In some cases indications of the savings expected to be achieved by some of the new technologies were obtained during the interviews. A brief description of each measure is given below and any evidence is provided below.

5.1 Passive

5.1.1 Remote control of supply

The supply to a house (or a circuit in a house) can be remotely controlled by a third party (usually an energy supplier). For instance, the Economy 7 teleswitch is used by suppliers to remotely control space and water heater loads.

The development of ‘direct switching’ or ‘direct control’ technology opens up the prospect of new tariffs (see Section 2.2.4) in which consumers allow suppliers to remotely switch off electricity during peak periods, thereby reducing the need for ‘spinning reserve’ (generating capacity that can be called on at short notice).

Direct switching requires a communication medium but not necessarily the same one as the smart meter. For example, it could be a radio teleswitch or general packet radio system (GPRS) signal from a supplier or distribution network operator (DNO). Alternatively, it could simply be a 'wireless' signal from the smart meter (e.g. perhaps triggered on a 'change of price' signal) to a particular appliance or an in-house energy management system (EdF Energy Networks interview).

The issue of interoperability will become increasingly important if the use of home area networks and advanced metering becomes more prevalent. Suppliers will increasingly need to communicate with appliances. Energy suppliers may be able to use interoperability as a marketing strategy to gain traction in the utility industry (by demonstrating that their advanced metering communications solutions have interoperability with other suppliers’ systems) (Lucero, 2008). The Energy Retail Association considers interoperability to be a key issue for suppliers and highlight the need for a government standard (ERA interview).

5.1.2 Dynamic demand control

Dynamic demand control (also known as dynamic response) entails remote control of time-flexible appliances, such as refrigerators, air conditioners, water heaters and pumps, which are turned off when there are power imbalances on the grid. Dynamic demand appliances, acting together, can reduce demand more rapidly than a traditional ‘spinning reserve’ generator can increase its supply (Baker and White, 2008).

The main benefit of the technology is maintaining supply and it will only have an indirect impact on carbon emissions. It may prove a useful tool given a move to greater penetration of intermittent renewable generation. The ability for appliances to act in this way will become increasingly useful in the future (as the grid is may to become inherently less stable due to much more smaller and 'non-synchronous' generation such as wind turbines (EdF Energy Networks interview).

5.1.3 Stand-by elimination

There are a number of technologies to reduce or eliminate the stand-by power consumption of electronic appliances e.g. Bye Bye Standby, Intelliplug, PowerSafer, and CheckTap. The Energy Using Products Directive may make many of these technologies redundant over time since it sets limits on the stand-by power of new appliances (see section 0).

Although there is potential for many appliances to have stand-by eliminated entirely this is not true for all appliances; some service providers advise that set-top boxes are left on for night-time updates. Complex boxes cannot be closed down to passive stand-by if full functionality is required. A cold start may also take some time (e.g. one to two minutes or longer)[62].

One option would be to use a control unit which reacts to a clock, sensor or remote control and switches the appliance on and off as needed. For example, if a set-top box needs to be updated during the night such a control unit could turn the box on for the time required to update the appliance and switch it of afterwards. Although such control units would require a small amount of stand-by power as well, this could reduce the stand-by required significantly.

Alternatively, Siderius et al. (2006) recommend power management for set-top boxes to establish which elements of the set-top box are needed by the user and increase or decrease the power for each element separately without losing functionality.

5.2 Space heating

There is a large range of heating control options from basic mechanical thermostats to a number of ‘advanced’ controls. It is estimated that around 10 million homes do not have standard modern heating controls (TACMA interview).

It is argued that current regulations do not provide sufficient incentives to improve the control of heating systems. For instance, It has been recognised that the standard assessment procedure (SAP) does not sufficiently assess the savings resulting from improved or advanced heating controls[63].

The SAP methodology assumes that, in the absence of adequate controls, boilers will be turned on and off frequently in order to maintain comfort conditions, but this may not be the case in practice. Lack of knowledge also leads to inefficient operation for instance using thermostats incorrectly (there is a view that turning up a thermostat heats up a home more quickly, even though the rate of heat increase remains constant). A lack of design attention on the size of boilers compared to size/ insulation levels of house may also lead to the over heating of houses (particularly if their insulation improves).

The three main options for improving heating controls (TACMA Interview) are:

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62 Apart from booting up internal software, this time is required to re-establish controlled access (CA), to allow pay-per-view decoding; and to download the hidden mapping data behind the programme guide that tells the receiver which programmes are on what frequency (Electronics Weekly, 2008).

63 TACMA has been working with the Market Transformation Programme and BRE.

- simple retrofit of existing thermostats with modern standard controls – cost effective – could be incentivised through CERT[64];
- advanced controls – commercial or near commercial – could be cost effective - need for further testing and validation; and
- integration of technology (see section 12 on future developments).

The basic elements of modern heating systems and the three options above are discussed in more detail below.

5.2.1 Modern heating systems

There are a number of technologies that can be installed to increase the effectiveness of an existing heating system and to optimise the overall operation of it.

Super-efficient condensing boilers

Modern condensing boilers offer a considerable reduction in fuel costs over standard boilers. This is because they convert more of the fuel they use into useful heat for the central heating system. They have a more effective heat exchanger that re-uses heat from the exhaust gases, rather than pushing it into the air outside. This is a tried and tested technology which has been successfully used for many years.

Since 2005, all new boilers installed in England & Wales must be condensing and include standard controls (see below). However the boilers may not perform to their quoted efficiency if the returning water temperature is too high as it may not be able to go into condensing mode. Heating controls that resolve this problem may result in an improved efficiency of around 10% (TACMA Interview).

In addition, the majority of heating systems are not optimally designed. In particular, boilers are often over-sized which can lead to low loads and reduced efficiency. This stems from the fact that boilers are typically sized based on ‘experience’ and judgement, which may not take sufficient account of insulation levels, for instance. There is also a tendency to build in margins to ensure that householders can always have all the heat and hot water they need, even if such peaks in demand are rare. We understand that there are a number of tools to help installers to be more accurate in their sizing but that they are not widely used.

Whilst there is considerable scope to improve the design of heating systems through better education and design tools, systems will only be optimised if the users’ (i.e. individuals) expectations are modified. In particular, ‘routine’ over-sizing has affected households’ expectations of the temperature that is ‘comfortable’, the time it takes to warm a house from cold, and the outside temperature at which the heating system should still cope (TACMA interview).

Collaboration between heating professionals, consumer organisations and behavioural experts could help deliver such change. Work is needed to review the way that systems are perceived and used, as well as to develop a practical design tool for installers (TACMA interview). A heating system review (which considers boiler size and control) could potentially be built into the Home Information Packs

64 Question remains as to how CERT can incentivise heating control due to current lack of accredited kit.

and could be introduced as an element in the energy audits recently proposed for inclusion under CERT.

Another consideration is the average age of the boiler stock; the efficiency of the existing stock is much lower than new boilers since the efficiency of a boiler would be expected to fall considerably over time. There is a need for more testing of in-situ boilers to gauge real life efficiency of current boilers since there is a lack of data on actual boiler efficiencies (TACMA Interview).

Electronic timer or programmer

The electronic timer or programmer decides when the boiler is able to run. The timer optimises the energy consumption of the boiler. For example, in spring and autumn there is no need to keep the heating on all day; a reasonably well insulated home can be left to cool down slowly with the heating timed to come on perhaps an hour or so before the householders return home from work.

Ideally, the timer would be connected to an outside thermostat and react to the outside temperature. A seven-day timer makes it possible to set a different heating pattern for weekdays and weekends. Some timers even allow different patterns for each day of the week; this can be useful for those working part-time or on shifts that vary from the conventional Monday-Friday work pattern.

Programmable and communicating thermostats

A programmable and communicating thermostat (PCT) is a fully-enabled two-way digital communication device. It can receive data, be programmed to respond to data and send data back about its actions. For example, a PCT can receive a price signal, be programmed with a set point and trigger prices at which to change the set point, and then it can change its settings on the home-owner’s behalf, depending on how it has been programmed.

Remotely controlled boilers

Remotely controlled boilers can be controlled over the internet and may be a useful tool for people that have erratic lifestyles or are short of time. Remotely controlled boilers consist of the following elements:

- a boiler enabled for remote diagnostics;
- a radio transceiver linked to the boiler and room thermostat;
- a gateway, connected to a normal telephone line, that communicates to the radio frequency (RF) transceiver of the boiler and that connects to a computer server through the internet; and
- server software that collects, processes and presents the data for the user(s).

Using such a system, the server or an operator can connect to and communicate with the boiler which enables it to be controlled from outside of the home and versatility of changing on/off settings at short notice. (Honeywell, 2007)

Room thermostat

A room thermostat is best located in a living room, rather than a hallway (as is commonly done) since the hall temperature can be affected in ways that do not affect the rest of the property e.g. by the front door being used. The thermostat records the home's temperature and if it is at or above the set level, stops the boiler from operating the central heating.

Thermostatic radiator control valves

Thermostatic Radiator Control Valves (also known as TRVs) are typically used for regulating the fluid flow to the radiators of central heating systems. They are provided with a regulating element which automatically controls the opening of the valve to keep ambient temperature of the room where they are installed constant at the set value. The number on the valve corresponds to a specific air temperature. Once the user has selected a number, the thermostatic valve will maintain this temperature. This prevents unwanted temperature rises and achieves considerable savings

The Radiator Booster

The Radiator Booster is a fan arrangement that increases heat transfer from radiator. Its manufacturer claims that it heats room up in up to half the time reducing the time the boiler needs to operate.

Zones

Homes can be heated on a zone basis so that different areas are heated to different temperatures. It is also possible to synchronise different systems so that the boiler only needs to come on a minimum number of times. Building Regulations require new homes have to have minimum of two zones e.g. downstairs is kept warmer than upstairs (use TRVs upstairs and thermostat downstairs).

5.2.2 Standard heating controls

Modern standard heating controls (set out in current building regulations) include the following features:

- Electronic programmer (can include various features such as the ability to keep house at different temperatures at different times of the day)
- Room thermostat (communication with boiler can be hard wired or wireless
- TRVs

However it is estimated that around 7 millions homes do not have either a programmable thermostat or a room thermostat or both. This rises to 10 million if it includes the number of homes without TRVs. Standard controls are being introduced with condensing boilers however currently limited to boiler replacement rate (around 20 years[65]) and need additional push.

Impact and cost effectiveness

Work done in Europe for the Energy Using Products Directive has found gas saving of around 10-30% if all three elements of a modern standard heating control system are installed (TACMA Interview) According to King’s Lynn & West Norfolk Council (2008), heating controls will pay for themselves in less than five years and save as much as 17% on the average heating bill.

65 Although it can vary e.g. between 15 and 25 years.

It is estimated that If the ten million homes that do not currently have modern 'standard' controls are given them they could save around 1.5MtC. Cost estimates vary, but could start at around £90 for a replacement room thermostat. EST estimates that savings are in the order of £92 a year i.e. payback of around 1 year. TRVs can be expensive to retrofit as have to work on pipe work – more for comfort but do produce savings (TACMA Interview).

5.2.3 Advanced heating controls

There are a large range of advanced heating control systems available which use various sensors to better control the operation of boiler. For example, infra-red sensors can be used to determine occupancy so that radiators or the boiler can be turned off when someone leaves the room or the house is empty. However, some advanced heating controls only work with new heating systems.

Sensors can be used to predict when a boiler needs to turn on, rather than just set a particular start-up time. Sensors can be placed either inside or outside to measure temperature; this optimises the operation of the boiler so that it works at a reduced load during warm spells. However there can be problems with the situation of exterior sensors e.g. they can be affected by shade, sun, wind.

Retrofitting a house with a large number of sensors may be impractical and expensive. For instance, sensors can be used on windows so that the heating is turned off when the windows are open. If this required the radiator (rather than the boiler) being turned off, it could involve a considerable number of sensors and controls.

Time proportional, chrono-proportional controls

One type of advanced heating control, the 'time-proportional, chrono-proportional' control, is considered to have significant potential to save energy (TACMA Interview).

These could theoretically be built into any temperature responding device but are typically incorporated in a room thermostat. They can avoid some of the disadvantages of the basic mechanical room thermostat, which tend to result in oscillating room temperatures and the boiler turning off when the target temperature is reached.

Instead chrono-proportional controls monitor how quickly the room heats up and more tightly controls boiler output, resulting in less fluctuation about the target temperature. This has several benefits:

- it provides closer control of room temperature reducing average boiler load; and
- it maintains a lower return water temperature thus allowing the boiler to operate in condensing mode (i.e. most efficiently) for longer.

Impact and cost effectiveness

The use of chrono-proportional controls could result in savings of around 10-15% (or a more conservative estimate of 7%) compared to a conventional room thermostat. We understand that Defra has provisionally agreed to run controls in test houses over next heating period to validate in-use savings.

In addition, there may be behavioural benefits: smaller oscillations enable the user to set the target temperature lower at the 'comfort' temperature rather than the higher average temp achieved using conventional controls. An ‘eco’ setting in programmers that has a lower target temperature could be used.

Although there are still issues around where the thermostat is situated, these are considered to be more promising than external sensors and offer a direct replacement for room thermostats (TACMA Interview).

5.3 Active

5.3.1 Home energy control units

Another expected area for innovation is the development of ‘energy hubs’ or home energy control units which provide energy management/appliance control. Home energy control units are sophisticated display units that can control appliances and switch electric circuits on and off. They allow for greater automation of appliances e.g. users can programme them to turn on a washing machine in the night. They could also be used to operate appliances based on microgeneration output.

Any number of appliances can be built into a home energy control unit, however costs increase with the level of sophistication of the system. Although such devices only control appliances connected to the electricity network in the home and are not connected to e.g. the security system, energy control units can be seen as an intermediate step to smart homes.

Only limited data is available which gives an indication on energy savings as a result of home energy control units. Craiger-Smith (2008) expects 20-25% savings from sophisticated display units which can control appliances. However, this figure includes behaviour change due to information on energy consumption and it is not clear whether the savings would be as high if home energy control units were used by a wide range of people.

5.3.2 Smart Appliances

Smart appliances have the ability to receive a signal from the utility company and react accordingly (the response depends on how they are programmed). For example, the devices could switch off should the utility company transmit a signal that says a period of high demand is about to occur. The smart appliances do not require interaction[66]; the devices can be accessed automatically by a third party like the utility company.

For example, a smart refrigerator has an automatic defrost feature that starts if the door is opened a certain number of times over a certain time period. During times of peak energy usage, the smart meter can signal that the defrost cycle should delay until an off-peak time. In the example of smart refrigerators and freezers, given that they can be configured to ensure that it does not have any negative impact on food quality there is no reduction in the quality of the function they provide. However, incentives may have to be provided to shift the use of washing, dish washing and tumble drying to off-peak periods (e.g. due to noise concerns). Trials show that people are sensitive about the ability to control room temperature manually and may not accept even small deviations from the desired room conditions.

66 Do not necessarily need to control via the display i.e. do not necessarily need an energy hub

However, recent surveys in the UK show that most respondents are willing to accept to set their domestic devices into a “smart operation mode”, where breaks in operation of two minutes maximum may occur. Most respondents were also willing to postpone the start of a washing machine, tumble dryers and dishwashers. (SMART-A 2008).Energy savings would occur at the supply side mainly due to load shifting and a reduction of losses (see section 10).

There are not many smart appliances currently available on the market however some are beginning to appear. GE will introduce the suite of Energy Management Enabled Appliances in the first quarter of 2009. The new “smart” appliances will include refrigerators, ranges, laundry pairs, microwave ovens, and dishwashers (General Electric 2008).In addition as smart appliances have built in features, there uptake would be limited by appliance turnover rates.

5.3.3 Smart home technologies

The definition of a smart home is:

“A dwelling incorporating a communications network that connects the key electrical appliances and services, and allows them to be remotely controlled, monitored or accessed.”(King 2003)

Although smart homes use smart appliances such as heating controls and smart meters, the essence of a smart home is its internal network of the appliances. It is important to differentiate between fully networked smart homes and smart features, as the latter can work without a home network.

- For example, a smart electricity meter can be installed with a VDU to display information on electricity use to residents. It can also communicate with energy suppliers, without a full home network.
- A full network would allow more sophisticated interaction between appliances. It would enable devices like security alarms and heating controls to interact, so that when a resident comes home and switches the alarm off the heating would know that someone is home and turn on automatically.

Following this definition and according to King (2003), a smart home compromises four key aspects:

1. an internal network through which devices talk to each other;
2. intelligent controls for managing the system;
3. sensors that collect information; and
4. smart features, such as intelligent heating systems, which respond to information from sensors or user instructions.

Appliances and services of a smart home can include security, home entertainment, domestic appliances, information and communication, health and environmental features.

Market potential in the UK

Although there has been considerable excitement about smart homes, the market potential for smart homes is viewed to be limited. For instance, a survey asked a range of stakeholders (such as building contractors, property developers and providers of smart home equipment) for their views on the potential markets for smart homes (Pragnell et al. 2000). Views differed significantly among the different groups:

- building contractors and property developers were typically sceptical about smart homes considering the costs and maintenance requirements;
- academics responding to the survey expressed a degree of scepticism about whether the capital expenditures for smart homes could be offset by energy and other savings; and
- equipment manufacturers strongly supported the idea of smart homes.

The evidence suggests that smart homes might be applicable at the extreme ends of the housing market; i.e. at the high end, where wealthy homeowners are interested in the latest technologies/ increased comfort and at the lower end, where issues such as security and fuel poverty play an important role. However, this would imply that, at current costs at least, the potential for the mass market is limited.

Furthermore, although the equipment can be retrofitted, smart homes are most practical and cost effective for new build dwellings. Turning an existing home into a smart home would cause disruption and require the substitution of existing equipment. Residents might be hesitant to replace working equipment they are familiar with and may also be put off by the upfront capital costs.

Smart meters and smart homes

Smart homes do not necessarily require smart meters. It is technically possible to connect different appliances without having a smart meter in place. For example, switching on the security system could automatically switch of the heating system and lighting. However, some consider smart meters to be critical to the success of smart features in general (Green Alliance 2008).

Potential savings and cost effectiveness

We understand that there are currently no solid cost estimates for smart homes. Furthermore, there are no reliable figures available for the potential for energy savings in smart homes (we have not been able to find case studies which provide data on the potential savings and costs). Smart houses could result in an increase in energy demand, particularly for those households that currently use low levels of energy. In addition, the high levels of automation involved may decrease the awareness and autonomy of the householder.

Whilst some smart homes may offer environmental benefits, other aspects such as increased convenience and security may be the main focus. There are also potential trade-offs between the different aspects. For example, if the use of consumer electronics becomes more convenient this may increase the amount residents use them increasing electricity consumption. Although it might be possible to design a smart home in a way that saves energy by controlling lighting and temperature, it depends very much on the overall design of the smart home whether it can generate significant energy savings.

5.4 Interaction with financial and behavioural measures

Electricity demand can then be moved (typically within the day or week), using a combination of technological measures (automation) and tariff measures (e.g. TOU tariffs covered in the next section). If the demand response is automated, and cannot be overridden by the consumer, the change in demand can be guaranteed. If a measure is voluntary however, or comes with some override facility, then there will be less certainty that it will be delivered.

Some loads in the home, for example heating, cooling, and refrigeration, could be controlled remotely without customer override (the Scottish Hydro Economy 7 load control for space heating is mentioned below). These applications are suitable for load control because they exhibit thermal latency and this allows some flexibility. However, other loads, for example washing machines and dishwashers, may be required urgently thus requiring load control override, hence TOU metering.

Conversely, load shaping can be purely voluntary, relying only on time of use tariffs, with no need for technological intervention through automation at all. Additionally, information can be provided to assist consumers in understanding what scope they have for load reduction and shifting.

6. TARIFFS: EVIDENCE OF SAVINGS

Most domestic customers have an electricity tariffs that charges a certain rate for electricity consumed up to a defined threshold and a lower rate for any electricity consumption in excess of the threshold. The higher rates for the first block of energy covers connection and maintenance costs.

The rate does not usually depend on the time of day the electricity is consumed and the majority of customers pay in arrears on a monthly or quarterly basis. There are however a growing number of innovative tariffs that vary price based on factors such as time of consumption, quality of electricity supply and maximum demand at any one time.

6.1 Pay in arrears

6.1.1 Increasing block tariffs

There have been suggestions that the current two-tier tariff[67] structure should be reversed so that rates increase as consumption increases to incentivise lower consumption levels. Whilst this tariff structure is common in some locations (e.g. South East Europe and Flanders) it is not common in the UK. Some argue that there would need to be a government mandate on all suppliers for the tariff to be introduced in the UK. *"Without such a mandate, many high-use consumers may switch to suppliers that do not use the tariff structure*." (Baker and White, 2008)

One complication in the use of rising block tariffs is the need to take into account household size in order to set an appropriate threshold above which the price increases. *"It may be difficult for suppliers to obtain such information, although one option would be to assume a default household size. This would incentivise consumers to provide suppliers with information about actual household size.*" (Baker and White, 2008)

Block tariffs may only appeal to a small number of customers that are confident that their consumption is low and will not exceed the threshold. However, there are examples of such an approach being accepted in some other areas (e.g. mobile phone contracts often offer a set number of minutes for free and then charge a higher rate above that threshold).

Given the information requirements to facilitate such a tariff, customers could benefit from real-time feedback on their energy consumption enabling them to better monitor their consumption and so to avoid moving into higher consumption blocks.

No evidence on the energy savings associated with increasing block tariffs has bee identified.

6.1.2 Time of use tariffs

Time-of-use (TOU) or time of day (TOD) tariffs offer different unit prices for varying blocks of time. The time-of-use periods will differ depending on the timing of peak system demand in the day, week or year, and may be year round or seasonal.

Other examples include:

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67 The initial higher tier enables suppliers to recoup various certain fixed costs – meter costs, network operator costs, CERT etc.

- ‘critical peak pricing tariffs’, which charge high per-unit rates for usage during designated ‘critical peak periods’; and

- ‘real-time pricing tariffs’, which reflect the wholesale price of electricity and therefore vary continuously over time.

Time-of-use tariffs are commonplace in the non-domestic market (Baker and White, 2008). However, there has been some reluctance in the UK to introduce TOU tariffs in the domestic sector, due to the perception that load-shifting potential in the UK is limited and concern over vulnerable households who may have lifestyles that make it difficult to alter their consumption patterns (Darby, 2007).

Whilst there may be less potential to load shift than in countries with significant air conditioning loads, even a small reduction in peak demand may result in carbon savings (see section 10 on supply side impacts). The need for better Demand Side Management (DSM) is expected to become increasingly important as the levels of intermittent generation increase, particularly if there is a move to the electrification of heat and road transport (see Section 10 on supply side impacts).

Economy 7

The *Economy 7* tariff is an existing, simple form of time-of-use tariff used in the UK. A consumer has access to two tariffs, a higher one for the day and a lower one for the night. The specific times when the lower rate applies vary between different regions and at different times of year (typically the seven-hour low price period starts at 1:30am during summer and 12:30am in winter).

Over 20% of UK households are on a economy 7 tariff. Almost all domestic consumers reliant on electricity for their main source of space heating use this tariff form. The off-peak electricity is also typically used for water heating. While many Economy 7 customers optimise they consumption by using electric storage radiators, many do not optimise other uses, such as washing machines or hot water (Baker and White, 2008).

Dynamic teleswitching

Another existing time-of-use tariff, used by about 10% (230,000) of domestic electricity consumers in Scotland, is dynamic teleswitching. Consumers on this tariff use a particular type of electricity meter that allows the supplier (or DNO) to switch supply remotely. Suppliers can instruct the DNO to switch tariff rates remotely, to encourage consumers to reduce demand during peak periods. However this may not be an attractive option since the tariff requires a special form of meter, consumers cannot switch to suppliers who do not offer this tariff (Baker and White, 2008).

Effectiveness

The evidence about the savings associated with flexible tariffs is mixed. There is some evidence of load shifting, however total electricity consumption may not be reduced but actually increased.

Darby (2006) cites reduction in peak demand of the order of 30%, however, it is not clear whether savings of this order could be achieved in the UK[68]. A trial of time-of-use tariffs, in conjunction with keypad meters, in Northern Ireland found that consumers reduced consumption by 10% at evening peak, resulting in a 1.5% cash

68 Nor is it clear whether the trials were statistically robust (refer to original source).

saving. However, the trial found that consumers slightly increased overall consumption. The research concluded that time-of-use tariffs have some impact on reducing peak demand, leading to lower bills, but little impact on overall energy consumption (Baker and White, 2008).

BERR assumes limited benefits from TOU tariffs (a 20% take up by consumers and a 3% bill reduction as a result) [69] (BERR, 2008a).

Automation versus behavioural change

Demand response is often characterised as being either behavioural or automated, however there is a range of levels of participation from manual to automatic interventions, with different approaches suiting different users.

Full real-time pricing of electricity is not necessary to achieve much of the benefit of demand response; because the national diurnal demand curve is relatively predictable TOU tariffs can reflect half hourly (HH) system prices and provoke appropriate responses. However, unless TOU prices are updated daily, they cannot facilitate demand response to events such as critical peaks where supply is scarce and expensive.

Loads that have thermal latency like heating and cooling systems can be remote controlled without the user being inconvenienced, provided temperatures are kept within acceptable limits. Conversely, services such as lighting and entertainment have less scope for such automated demand response. Other loads, such as wet appliances, could also be deferred or paused automatically but it is likely that under certain circumstances customers would want to be able to override any such control.

Load control technology can be facilitated in the absence of smart metering but if participation is optional as suggested above, then metering is required to reward participants.

There may be a balance between the benefits of increased automation with decreased consumer participation. Different individuals may favour different levels of automation. In schemes that use critical peak pricing, consumers typically report that they would prefer options for automated load shedding as opposed to purely voluntary load reduction (IEA, 2005).

6.1.3 Lower rate for lower security of supply / Interruptible loads

Internationally there are number of tariff schemes where non-essential loads are remotely controlled. Historically these arrangements have been available to larger commercial and industrial sectors, but there is some indication that they are moving down to smaller consumers. Some domestic examples include:

- control of electrical heating e.g. Scottish Hydro use teleswitch and economy 7 tariff;
- hot water system control in South Africa;
- interruptible ‘circuit’ option in the new Italian meter scheme.

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69 Due to the limited amount of load shifting that may be possible through standard ‘wet’ household appliances; the unpredictable developments in ToU tariffs; international evidence; and the likeliness of take up of ToU tariffs in Great Britain.

No evidence on customer energy savings associated with tariffs of this sort were found, however demand shifting may result in reduced system losses.

6.2 Pre-payment tariffs

A number of customers in the UK are charged on pre-payment or ‘pay as you go’ tariffs. According to National Energy Action (2008) there are 5.8 million prepayment meters in Great Britain of which 3.6 million are used by electricity consumers and 2.2 million by gas consumers.

Prepayment meter users are typically on lower than average incomes (21% of gas consumers on pre-payment meter have an annual income of less than £10,000; the equivalent figure for low-income electricity consumers is 23%). Prepayment meters are more likely to be used by lone parents, people in receipt of welfare benefits, those with no bank account and customers with payment difficulties (National Energy Action 2008).

As they are typically more expensive per kWh of energy than those paid in arrears this raises concerns around fuel poverty. The Government has said that pre-payment consumers will be encouraged to move to direct debit and that regulation may be required to ensure that those using pre-payment meters do not face unjustifiably higher tariffs than other customers using other payment methods[70].

The BERR Fuel Poverty Advisory Group noted the large differential in their sixth annual report. “*The price differentials between customers using different payment methods remain extremely large. Customers – generally with lower incomes – using prepayment meters for gas and electricity pay as much as £145 pa more than those paying by direct debit or online and those paying by cash/cheque pay about £85 more than those on direct debit. These are huge differentials, much higher than those of three years ago. This issue of differentials and of the prices paid by low income customers is now acknowledged by the Government and Ofgem and there is hope of some improvement*” (Fuel Poverty Advisory Group, 2008).

However, whilst Ofgem expressed concern about tariff differentials between standard credit and pre-payment types in its report on initial findings from the Energy Supply Probe, it considers average current pre-payment premiums to be justified based on their cost estimates (Ofgem, 2008b).

The use of pre-payment meters may enable consumers to better control the amount they are spending due to an increase in the frequency of feedback on electricity consumption and the psychological difference in paying outright for something rather than building up debt.

A study of British householders on prepayment tariffs (mostly low-income households) showed that over 80% of electricity customers and 70% of gas users wished to continue with this method of payment even though the majority were aware that it was more expensive than payment in arrears (Waddams Price, 2001).

There is some evidence that the use of pre-payment meters results in savings at the meter, however it is unclear whether this is due to a decrease in comfort levels, a decrease in non-essential electricity use or an increase in energy efficiency.

70 In its announcement of 10 September 2008

The key meters used to facilitate such tariffs are 'semi-smart' i.e. they allow the transfer of information such as tariff-changes and meter reading data to and from the key code at the payment point/ shop (Darby, 2006).

Key-pad meters have been used in Northern Ireland and initial results suggest savings of around 3% (Owen and Ward, 2006)[71]. The trial in Northern Ireland noted the additional benefit that regular information on electricity consumption had on reducing consumption. In addition to providing greater control over spend, it has removed any differential in price between pay in arrears and pre-payment tariffs. Key-pad meters are also used in South Africa. A utility in Ontario found that 25% of their customers who took part in a 'pay as you go' trial used between 15 - 20% less energy than they were doing under the traditional system of payment, because the display unit increased awareness around consumption (Darby, 2006).

71 Note the study mentioned above which used a combination of key-pad meters with flexible tariffs found that there was a slight increase in consumption.

SECTION 2: POTENTIAL IMPACT OF THESE MEASURES IN THE SHORT TERM

7. HOW MUCH ENERGY AND CARBON CAN THESE TOOLS SAVE?

We have used the literature review to search for qualitative and quantitative information on the extent to which these behavioural measures can reduce electricity and gas use in the domestic sector. This section summarises our findings and highlights in qualitative terms how great an impact the different measures could have on energy savings in the future.

Some evidence of reductions in energy consumption was found for these measures however a number of factors limit confidence in the figures found.

- **Persistence of savings** – many of the trials undertaken assessed energy consumption in the short- to medium-term and it is not clear whether the savings observed (especially those due to behavioural change) would continue in the long-term.
- **Packages** – many studies consider the impact of a package of measures and it is therefore difficult to ascertain the impact of an individual measure.
- **Unrepresentative samples** – many of the studies involved a small sample size with self selecting participants. It may not be appropriate to assume that the magnitude of savings found is applicable to the wider population.
- **Location** - some of the studies took place in other countries and may not be representative of the potential savings in the UK. For example most trials and studies to date have examined effects on electricity use only and in homes with electric heating, whereas most UK homes have gas heating[72].

This report includes quantified savings from a range of primary research; the original source should be referred to for details of the sample selection and statistical robustness.

7.1 Summary of short term impact of tools

As we have noted in the sections above, hard evidence about how great a saving these types of measure could deliver is limited. In many cases, the conclusions drawn from the literature are only as strong as ‘it depends…’. With this in mind we have attempted to provide our view of the measures that have the greatest potential to either reduce consumption beyond the levels projected under existing policies or to reduce peak electricity demand in the short term in the table below. It ranks them from largest to smallest additional energy savings potential: ‘considerable’, ‘some potential’, then ‘limited’. This estimate takes into account both the scale of impact that the tools could have, their cost effectiveness and the time it would take to implement such an approach.

72 In the UK there may be more scope to reduce gas use with smart metering (heating and hot water uses) (Owen and Ward, 2006)

Table 10 Overview of impact of different types of tools

Tools	Impact description	Potential to deliver additional savings
Information tools: Awareness raising		
General education and tailored information for both consumers and supply chain	Essential for good uptake of all measures. Need to raise and maintain awareness of climate change in general, key emission sources and the benefits of energy efficiency, and find audience-specific anchors to bind persuasion and change attitudes. Tailored advice is required to maximise savings. However, education alone may not deliver energy savings.	Considerable (in conjunction with other measures)
Better billing	Provides the opportunity to give greater feedback to customers on energy consumption (whether historic and/or comparative). Some argue that the increased awareness caused by better billing could result in significant additional energy savings, but this is not guaranteed. For instance, there is the risk that people fail to even open their bills (especially if sent electronically and paid via direct debit). Better billing is supported by the Government's Better Billing (and Metering) programme which is in progress. The provision of historic information on energy consumption in energy bills will be mandatory from 1 January 2009 (OPSI, 2008b).	Some potential
Total energy consumption raw data	Reasonable potential for standard gas or electricity meter to be used to give a very basic form of energy consumption feedback[73]. However, meters are often out of sight and many bills are based on estimated readings (although this is improving). Householders could be encouraged to collect and analyse data (e.g. by reporting the figures regularly by phone or entering them into a website) which could result in some behavioural change.	Some potential (in conjunction with other measures)

73 Such data is a prerequisite for many of the other tools discussed, and so its potential impact is ranked as being higher than, say, real time display units, which similarly do not in themselves trigger a behaviour change but that can be used to facilitate one.

Tools	Impact description	Potential to deliver additional savings
Presentation of interpreted energy consumption data	Raw data can be presented to the householder in a more meaningful way. There are a number of methods available: - Real time digital display: simple and cost effective but impact on energy use savings may wane over time. If first few months of use can spur behavioural change then long-term savings may be gained. - Ambient signals (colour, flashing lights) may help to sustain customer interest but customers may find them intrusive. - Interactive internet sites or TVs may be effective for some. Problem of sustaining interest in software/ community websites in the medium- to long-term may be greater than for VDUs in a prominent position in the home. - Community websites where people compete with each other to reduce their energy consumption increase peer pressure and help to sustain motivation levels in the medium-long term.	Some potential (in conjunction with other measures)
Appliance-level consumption data	There are a number of ways to monitor the contribution individual appliances make to total consumption[74]. - Visual display units (VDUs) showing real time electricity consumption data (can provide some crude feedback) - Sub-metering for intrusive monitoring (is not currently cost effective but offers a useful tool to better understand actual domestic energy use) - Non-intrusive monitoring based on power signature could enable remote energy audits to be undertaken. The main barrier is currently cost.	Some potential
Information tools: Information on efficiency of consumer goods and buildings		
Energy Labels	Current labelling scheme (under Energy Labelling Directive) has helped raised customer awareness. However, it excludes a number of goods such as electronic equipment which are increasing in number per household. Rating schemes can limit perceptions of what is available and gives neither indication of overall energy consumption nor importance of operation and maintenance.	Some potential
Procurement advice	May be essential for some users to choose the best option, and could have benefits where economies of scale (e.g. social landlords). However, wide-scale limited potential for passive provision as generally only motivated individuals will seek out information – use of energy labels at point of purchase may be more effective.	Limited

74 Could also be a useful tool for policy maker/researchers etc. There is a need for more appliance level data to better understand both actual performance of appliances and consumer behaviour.

Tools	Impact description	Potential to deliver additional savings
Information tools: Information on reducing emissions		
Generic advice on energy reductions	Mobilising information is absolutely essential, but important to change attitude (persuade) first so that more people are prepared to seek out and act on the mobilising information.	Some potential
Tailored advice: energy audits	A series of audits can give a stream of feedback, guiding a motivated consumer towards a target for reductions to consumption. However, given their cost, more formal audits are likely to be infrequent, but can still indicate degrees of progress. Recently proposed to be added to CERT list of measures to qualify for suppliers' obligation.	Limited[75]
Technological tools: passive tools		
Retrofit heating controls	A large number of households do not have standard modern heating controls (room thermostat, electronic programmer and thermostatic radiator valves) and there is a large potential for saving energy by retrofitting all homes with these controls. Currently the retrofit of heating controls is linked to boiler replacement which slows down implementation rates. There is scope to accelerate the rate of uptake over and above that already required under CERT. For instance, the current SAP rating may not sufficiently reflect the benefits of retrofitting heating controls.	Considerable
Remote control of supply	Development of 'direct switching' or 'direct control' technology allows suppliers to remotely switch off electricity during peak periods. This helps ensure security of supply and reduces the costs of reserve provision, so reducing the costs to the customer. Direct switching requires a communication medium but not necessarily the same one as the smart meter.	Some potential
Stand-by elimination	One part of the Energy Using Products Directive may reduce standby to a minimum. However, stand-by could be eliminated entirely resulting in considerable additional savings. This would reduce the ease of operation of some appliances e.g. user would have to wait for several minutes for set-top box to update when it was turned on.	Some potential

75 Unless not one-off or when accompanied by follow-up support to change, when potential is greater.

Tools	Impact description	Potential to deliver additional savings
Advanced heating controls	There has been a large amount of innovation in heating controls in recent years and there is the potential to control heating systems much more optimally. In particular, time-proportional, chrono-proportional controls may offer significant savings however there is a lack of data currently available. The current SAP rating does not recognise advanced heating controls like time proportional, chrono-proportional controls which could result in significant savings.	Some potential[76]
Dynamic demand control	This allows for the remote control of time-flexible appliances such as freezers so that they are turned off when there are power imbalances on the grid. The main benefit of the technology is maintaining supply and it will only have an indirect impact on carbon emissions. It may prove a useful tool given a move to greater penetration of intermittent renewable generation.	Limited[77]
Automated lighting	Motion sensors and light sensors can be used to turn off lights when not required. However they are expensive for retrofit in particular and may not result in significant savings.	Limited
Shower heads	Affecting water use in this way may have some impact on energy use (by reducing the flow of hot water however energy savings minimal). Options to reduce the amount of time showering or to reduce the water temperature may have a greater impact.	Limited
Heat recovery / exchangers	These can reduce both space heating and hot water requirements. However, they are difficult to retrofit and payback back periods are considerable. May be a useful feature in low energy new build.	Limited
Technological tools: active tools		
Programmable and communicating thermostat	Can be used as part of an advanced heating control system. Allows for two-way communication so could receive price signals.	Some potential
Home energy hubs	These are sophisticated visual display units that can control appliances. They allow for greater automation of appliances e.g. they can be programmed to turn on a washing machine in the night. They could also be used to operate appliances based on microgeneration output. Home hubs may be an interim step to smart homes.	Some potential

76 Evidence in this area is particularly limited at the moment and additional research could help establish this with more certainty.

77 Can help to maintain supply but will not have a direct impact on household energy or carbon.

Tools	Impact description	Potential to deliver additional savings
Smart appliances	This term refers to appliances that can communicate with remote third parties e.g. suppliers and/or have built-in energy efficiency design features such as automatic defrost. They may facilitate some load shifting however not many models are currently available and uptake will be slowed by appliance turnover.	Limited
Smart Homes	A Smart House can include energy savings features such as advanced heating controls and Smart Appliances. Whilst they offer many other security and health related benefits the energy consumption will depend on the overall design and operation of the house and there is a lack of evidence around energy savings[78]. Smart houses could result in increased energy demand, particularly for those households that currently use low levels of energy. The high levels of automation may reduce end user participation. A Smart Home does not necessarily require a smart meter within the home area network (HAN) to function, providing the home system is not communicating with outside parties.	Limited
Tariffs		
Time of Use (TOU)	Time of Use tariffs may offer good potential for load shifting which may become increasingly important in future to help manage security of supply and as intermittent generation levels increase79. In order to move to fully flexible tariffs there is a need to effectively communicate any changes in tariff which would suggest the need for smart meters with advanced meter management (AMM) functionality. They may not be appropriate for the whole population however – some vulnerable households may have lifestyles that make it difficult to alter their consumption patterns.	Some potential
Lower rate for lower security of supply (interruptible) / interruptible appliance	This tariff type is used to shift loads by remote control of appliances by suppliers[80]. This type of tariff would help provide some guarantee of savings delivery at peak if there Is not a manual override.	Some potential

78 They are typically more expensive than standard homes and have high maintenance requirements and it is therefore questionable whether they are cost effective.

79 There may be less potential to load shift than in countries with significant air conditioning loads but even a small reduction in peak demand may result in carbon savings.

80 One case of their use in domestic sector has been identified (for hot water in South Africa) however they are more commonly used in the commercial and industrial sectors.

Tools	Impact description	Potential to deliver additional savings
Increasing block tariffs	Increasing block tariffs have been used in other European countries and may provide customers with an incentive to reduce electricity consumption. They may only appeal to small number of consumers that are confident that their consumption is very low. Setting an appropriate threshold for each customer might be difficult. Given information requirements to facilitate such tariffs, customers could benefit from real-time feedback on their energy consumption enabling them to better monitor their consumption and avoid moving into higher consumption blocks.	Limited
'Pay as you go'	There is some evidence that pre-payments result in savings at the meter. However energy tariffs are typically more expensive per kWh of energy than those paid in arrears. Since they are common in social housing, this raises concerns around fuel poverty. The use of pre-payment meters may enable consumers to better control the amount they are spending due to an increase in the frequency of feedback on electricity consumption and the psychological difference in paying outright for something rather than building up debt.	Limited

8. POLICY INTERACTIONS WITH ENERGY DEMAND

To consider the potential impact of demand side measures on energy consumption and supply side implications, we need to consider the extent to which they may already be incentivised by government policies and measures. This helps to establish which areas are already being targeted and where additional policy support may be required. It also helps to identify how existing policies may change the way that energy will be used in the long-term and the resulting potential for demand side savings.

We in the text below we have considered those policies that are already implemented, have detailed plans in place, are under consultation and are at a draft stage. We have considered how they may impact on energy use in the domestic sector or encourage carbon savings from it.

8.1 Summary of interactions identified

Energy saving, energy efficiency and low carbon energy policies

- The shared goals of many of the policies considered are the objectives set out in the Energy White Paper i.e. reduction of fuel poverty (including cost of energy), reduction in energy use, increased security of supply and carbon reductions.
- There is a wide range of policies aimed at reducing (total and consequently peak) energy demand use via technological change:
  - incentivising the energy efficiency of domestic appliances;
  - requiring better building standards for new properties;
  - improving the energy efficiency of the existing building fabric; and
  - encouraging the uptake of energy efficiency measures to, and in, the home.
- Some small number of policies may result in increased energy consumptions amongst homeowners (specifically those aimed at addressing fuel poverty).
- Running alongside these are interventions that raise awareness of climate change, energy use in the domestic sector and opportunities to reduce it. These policies may also drive behavioural change.
- There are currently no policies aimed at influencing the time of energy use amongst households i.e. they do not typically encourage load shaping.
- Several policies are aimed at impacting on the carbon intensity of the domestic sector’s fuel choice, particularly encouraging the uptake of renewables or other more efficient distributed generation and microgeneration.

Indirect impacts

- A range of policies may also have a less direct impact on energy use and carbon emissions in the domestic sector.
- This can be via policies that aim to reduce the environmental impact of appliances in the home, with a knock-on effect for energy.

  - Policies that reduce hot water use will reduce the amount of energy required to heat it.

  - Intervention that provides information on the 'environment' will also influence the domestic sector's view of climate change, and can raise their awareness of their impact and mitigation options.

- The uptake of electric vehicles is currently incentivised to some extent by e.g. via fuel duty, road and congestion charge and road tax exemption.

Overlaps

- A number of policies overlap with each other and so it would be wrong to attribute additional carbon savings to each of them.

  - For example the energy efficiency of a domestic appliance will be targeted by both the EU Eco-Design of Energy Using Products Directive and the EU Energy Labelling Scheme.

- The energy efficiency of the building is tackled by a large number of policies. Part L/H of the Building Regulations and the Code for Sustainable Homes affect new building in particular, while others typically focus on existing properties e.g. Warm Front and CERT.

8.2 Policies reviewed

We have reviewed the key policies that fall broadly within the categories:

- buildings: better building standards for homes and home fabric

- renewables: broad renewables strategy and specifically microgeneration

- energy efficiency and fuel poverty: including information to end users about their own energy use in homes

- product standards.

These include Government policies designed to tackle energy efficiency, energy savings and carbon emissions from households[81] and which are discussed in the text below. Other areas that may also impact on energy use for and are discussed in more detail in Chapter 9 include:

- fiscal instruments e.g. reduced VAT rates on energy efficiency materials and technologies;

- local government energy efficiency activity e.g. reporting strategy and Housing Act;

- policies encouraging individual and community action to tackle climate change.

Policies affecting transport and waste in the domestic sector have also been considered.

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[81] Available from: http://www.defra.gov.uk/environment/climatechange/uk/household/index.htm (Accessed September 2008)

8.3 Buildings: improved energy efficiency of homes

Policies that make homes more energy efficient do so by addressing the existing building stock and also the building fabric of new homes. New homes can be required to be energy efficient by setting standards for energy efficient design right from the start. There is a comparatively low rate of construction and long lifespan of household buildings, so turnover of households is slow (around two-thirds of the housing stock that will be standing in 2050 will have been built before 2005[82] [83]). Therefore, although ensuring new homes are energy efficient can only go so far; it is also crucial that the energy performance of the existing UK building stock is also tackled (Green Alliance Interview).

Policies designed to improve energy efficiency of homes include:

- Directive on Energy Performance of Buildings (2002/91/EC) / Housing Act 2004;
- Building Regulations Part H and Part L;
- Home Energy Conservation Act 1995;
- Decent Homes;
- Code for Sustainable Homes; and
- Relief from Stamp Duty Land Tax on zero carbon homes (until 2012).

8.3.1 Directive on Energy Performance of Buildings (2002/91/EC) (EPBD) / Housing Act 2004

The principal objective of this Act is to promote the improvement of the energy performance of buildings within the EU through cost-effective measures. In the UK, the EPBD has been translated into regulation via the Housing Act 2004, which introduces Home Information Packs (HIPs) including Energy Performance Certificates (EPCs) for every home on sale.

EPCs must be made available to prospective purchasers or tenants, to inform their choice of property. By providing information on the energy efficiency of a home using an A-G rating system, the EPC may improve homeowners' awareness of energy use in their home. Since the EPC is valid for 10 years (it can be renewed earlier than this through choice) it will not typically provide a facility to monitor the impact of introducing energy savings technologies or changing energy use behaviours.

There are some other limitations to their expected impact. Landlords only need to get an EPC when they first rent out the property to a new tenant, so properties with existing tenants will not require an EPC until the tenant changes. There is no requirement for an EPC if renting out rooms to a lodger or house share (DCLG, 2008).

It is not possible to evaluate the impact EPCs will have on the housing market at this point due to the short time for which it has been running. Their impact will depend on a range of factors, including awareness and understanding. Both of

82 The Household Energy Supplier Obligation: A call for evidence, Defra, June 2007

83 Review of Sustainability of Existing Buildings :www.communities.gov.uk/pub/291/TheEnergyEfficiencyofDwellingsInitialAnalysis_id1506291.pdf

these factors will be affected by the way that the information is presented on the EPC and how it is ensured that it is information energy users consult and absorb. Ultimately they will only have an impact if they result in house price differentials so that they encourage the uptake of more measures (although these may not be additional to CERT or the Supplier Obligation (SO)).

8.3.2 Building Regulations

Building Regulations specify standards of construction and design for new dwellings and for certain categories of building work carried out to existing buildings. Since 2000, Part L of Schedule 1 of the England and Wales Regulations has included standards to improve energy efficiency. These were revised in 2002 and 2005-06. The standards to improve energy efficiency have been strengthened by 40% for new homes built from 2006, compared to pre-April 2002.

Building Regulations are expected to achieve nearly half the energy savings of the UK household sector by 2020[84]. Such expectations are based on the assumption that the construction industry will fully comply with the regulations. However, poor understanding, poor workmanship, and local authorities' limited resources for enforcing compliance limit the effectiveness of the Building Regulations (NAO 2008).

Also, some of the measures required are only partially incentivised by the regulations. For example, advanced heating controls are installed alongside boiler replacement, but there the is no requirement to fit controls with existing boilers and replacement of controls will only be partly driven by CERT. Boiler service companies could potentially install heating controls at the same time that they do maintenance work (TACMA Interview).

8.3.3 Home Energy Conservation Act 1995

The Home Energy Conservation Act 1995 (HECA) requires every UK local authority with housing responsibilities i.e. 'energy conservation authorities' to prepare, publish and submit to the Secretary of State an energy conservation report identifying: practicable and cost-effective measures to significantly improve the energy efficiency of all residential accommodation in their area; and report on progress made in implementing the measures.

HECA does not incentivise particular measures; rather it is a reporting tool which enables government and local authorities to better understand energy efficiency improvements in the housing stock. This can then inform policies and measures tackling energy efficiency. It is not possible to estimate the impact of HECA and we expect it to have indirect impacts on other policies rather than directly affecting energy consumption.

8.3.4 Code for Sustainable Homes

The Code measures the sustainability of a new home against categories of sustainable design, rating the 'whole home' as a complete package. A mandatory rating against the Code was implemented for all new homes from 1 May 2008 (before that it was mandatory for social housing only).

The Code uses a 1 to 6 star rating system to communicate the overall sustainability performance of a new home. It also sets minimum standards for energy and water use at each level, as well as requiring entry level requirements for waste and

84 Excluding the SO and extensions to CERT.

materials. For example, Code Level 1 represents a 10% improvement in energy efficiency over the 2006 Building Regulations. The aim is to make homes more energy and water efficient, produce fewer carbon emissions and generally to be better for the environment.

Similarly to the Building Regulations, non-compliance with the Code might reduce the potential for energy savings. Furthermore, there is evidence that supply chains and skills to deal with energy efficient products are not developed to the extent required (Wingfield et al. 2008).

8.3.5 Relief from Stamp Duty Land Tax on zero carbon homes

In order to provide incentive for zero carbon homes the Treasury announced a relief from stamp duty on new homes meeting the zero carbon criteria. The relief will provide exemption from tax liability when house costs less than £500,000, and will provide a £15,000 reduction in tax liability to all homes worth more than £500,000.

So far, only a few homes with zero carbon emissions have been built and it is difficult to estimate the impact the relief from Stamp Duty will have on the future uptake of zero carbon homes and the associated energy savings.

8.3.6 Decent Homes

This is a DCLG policy with the target of bringing 95% of all social housing up to a ‘decent’ standard by 2010. A decent home is defined as 'warm, weatherproof and has reasonably modern conditions'.

The Decent Homes standard is designed to trigger action, not as a target to be met. The standard requires that all homes should have a reasonable degree of thermal comfort (defined as having an efficient heating system and effective insulation).

Houses with gas- or oil-fired programmable central heating need to have either cavity wall insulation or at least 50mm loft insulation (if feasible). Homes with liquefied petroleum gas (LPG), solid fuel-fired programmable central heating, or electric storage heaters require either cavity wall insulation or at least 200mm loft insulation (if feasible). At present, a lower standard of insulation is required in ‘hard to treat’ homes; those without cavity wall construction and/or without loft space (Energy Saving Trust 2008).

Defra expects 95% of social homes to be decent with regard to energy efficiency requirements by 2010 (Defra 2007b). Expected savings beyond 2010 in addition to what has been already achieved are likely to be minor, based on evidence from the NAO (2008).

8.3.7 EU Directive on Energy End-Use Efficiency and Energy Services (ESD)

The EU Directive on Energy End-Use Efficiency and Energy Services (ESD) sets the overall target for energy efficiency in the UK so is aimed at energy efficiency of buildings i.e. homes and energy use within homes. It impacts on both providers and users of energy. It was introduced to enhance the cost effective improvement of energy end use efficiency in European Member States.

The main requirements of the Directive are: national indicative energy savings target of 9% by 2017. Member States like the UK must place obligations on energy suppliers and distributors to promote energy efficiency. It also sets out requirements on metering and billing to allow consumers to make better informed decisions about their energy use.

In response to the ESD, the UK Energy Efficiency Action Plan 2007 has been compiled. Articles 4 and 14 of the ESD on setting a UK energy target and monitoring of that target are implemented with this UK plan. It announced that Government expects to double the EU indicative energy saving target of 9% over nine years by 2017, and deliver 18% saving.[85] Two further plans will be produced before July 2011 and July 2014 and Defra will continue to work on these throughout the lifetime of the Directive.

The policies laid out in the UK Energy Efficiency Action Plan are aimed at impacting on energy use by reducing energy use for heating in households, reduced electricity and gas use (from the baseload and peak generation).

8.4 Energy efficiency within homes

In addition to policies aimed at the building fabric, other policies aim to deliver energy savings within homes.

8.4.1 Fuel poverty

The main policies aimed at reducing fuel poverty in the UK through energy efficiency gains in the home are the Warm Front in England (and its equivalents in Scotland, Northern Ireland and Wales) and Decent Homes above.

Warm Front

Warm Front[86] is the Government's main grant-funded programme for tackling fuel poverty. Grants are available for vulnerable private sector households to install energy efficiency measures, including central heating and insulation. Up to £2,700 is available for families and the disabled, with up to £4,000 for the installation of oil fired central heating). Further measures as part of the Warm Front were announced (Defra 2004):

- Offer oil central heating, once other low carbon solutions have been considered.
- Increase the energy efficiency Standard Assessment Procedure2 (SAP) rating of each property. Where practicable the aim is to achieve a SAP rating of 65, a level where there is a minimal risk of any household being in fuel poverty.

Government funding for the 2008-11 period for the scheme is just over £800 million which could help up to 400,000 vulnerable households. Over 1.6 million people in England have received assistance since 2000[87]. Warm Front claims to have achieved an average annual saving per household targeted of 13GJ (3,611 kWh) in 2008.

However, according to the NAO (2003) some homes saw a dramatic rise in energy efficiency but around 20% of grants resulted in little or no improvement in the energy efficiency of homes. The NAO also highlighted that the energy efficiency of a home does not impact on the eligibility of grant applicants.

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85 Our modelling work described below suggest that this target falls between our Additional Measures scenario that achieves an electricity and gas reduction of 7% from the projected energy consumption under existing policies and our 'Idealistic' scenario that achieves a 23% reduction from projected energy consumption under existing policies.

86 The scheme was launched in June 2000 (initially known as the Home Energy Efficiency Scheme) (Defra 2004)

87 www.defra.gov.uk

Similar programmes are established in Scotland (Central Heating Programme and Warm Deal), Northern Ireland (Warm Homes Scheme) and Wales (Home Energy Efficiency Scheme).

8.4.2 Carbon Emissions Reduction Target (CERT)

The Carbon Emissions Reduction Target (CERT: running from April 2008 until 2011) obligates energy suppliers to achieve targets for promoting reductions in carbon emissions in the household sector. It is the principal driver of energy efficiency improvements in existing homes in Great Britain and follows on from the Energy Efficiency Commitment (EEC). Suppliers must direct at least 40% of carbon savings to a priority group of low-income and elderly consumers. Under CERT suppliers can achieve their carbon emissions reduction obligation by promotion of measures for:

- achieving improvements in energy efficiency;
- increasing the amount of electricity generated or heat produced by microgeneration;
- increasing the amount of heat produced by any plant which relies wholly or mainly on wood; or
- reducing energy consumption.

Extensions to CERT were recently proposed by the Government (in September 2008, note these are still subject to consultation). CERT is expected to deliver overall lifetime carbon dioxide savings of 154MtCO_2, equivalent to annual net savings of 4.2MtCO_2 by 2010 (OPSI, 2008a)[88]. CERT only targets a small proportion of the population and there is considerable scope to promote the measures included in CERT across the wider population.

The impact of CERT on final energy consumption is not measured. Instead monitoring of the measures can take one of following forms:

- technical monitoring of a sample of households;
- customer satisfaction monitoring; and
- customer utilisation monitoring e.g. to determine use of free CFLs and electronics.

Different levels of monitoring are required for the various standard actions. However, whilst monitoring of demonstration measures is required, is it not prescribed in terms of sample size and form of monitoring.

The lack of monitoring on final energy consumption may mean that the projected savings from CERT are not met. For example the savings associated with energy saving light-bulbs can only be estimated based on the proportion of the households sampled that installed the light-bulbs.

CERT uses a measures- rather than outcome-based approach; improved data on domestic energy consumption (which would be provided by smart metering) would be required to move towards the latter approach. The uptake of new technologies under CERT may take time. Heating controls for example are not expected to be

88 Not including recent increase in target.

driven by CERT as they are given insufficient credit and there is a lack of certified controls.

Future Supplier Obligation

The 2007 Energy White Paper reaffirmed the Government's commitment to maintain some form of obligation on household energy suppliers until at least 2020, with an ambition level at least equal to that under CERT. At the end of 2007, Government launched a call for evidence on the Supplier Obligation post 2011 (Defra, 2007a) (see Figure 6 below).

Figure 6 Call for evidence – the household energy Supplier Obligation from 2011

The call for evidence on the SO from 2011 asked a number of questions about the design of the next SO such as whether the SO should move from a measures-based approach to an outcomes-based approach such as a cap and trade system.

Views on this matter were mixed: eleven organisations preferred a cap and trade approach whilst seven preferred a measures-based approach. One said that a CERT-style system should continue for now but maybe switch to cap and trade following successful trials. Six organisations put forward entirely different frameworks. For example, Ofgem suggested that the Government consider an energy or carbon tax instead.

The Call for Evidence put forward an indicative set of measures and associated energy and carbon reductions for the period 2011 to 2020 and asked for comments.

- Several concerns were expressed, the main one of which was that Defra was being optimistic in expecting 1MtC (3.67MtCO2)[89], or more than one quarter of the savings, to come from behaviour change such as more people switching off or dimming superfluous light.

- Two representatives from the insulation industry, on the other hand, thought the figures given in the Call for Evidence under-represented the potential for cavity wall insulation.

In their response to the call for evidence, Government noted that is too early to make any decisions on the shape of the post-2011 obligation, and committed itself to undertaking further analysis and evaluation of the options, leading to a further public consultation which is likely to be published by Autumn 2008.

8.5 Improved information given to end users about their own energy use in homes

In addition to information provision by Government informing individuals about climate change and their impact on it (e.g. Act On CO2, Climate Change Fund), its agencies and bodies like the Carbon Trust and Energy Savings Trust also provide help and advice (see Section 4.1). Other policies and activities that will result in the provision of information to individuals are discussed below.

89 Annual savings from behaviour change in our very ambitious 'Step Change' scenario were 4.9MtCO_2 by 2020 however annual savings from behaviour change in our more realistic 'additional measures' scenario were only 0.6MtCO_2.

8.5.1 Directive on Energy Performance of Buildings (2002/91/EC) (EPBD) / Housing Act 2004

Both the EU Directive on Energy Performance of Buildings (2002/91/EC) and Home Information Packs including Energy Performance Certificates are outlined in the above section. They are both concerned with improving information given to domestic end users about energy use in homes.

8.5.2 Energy Labelling Directive

The labelling of goods under the Energy Labelling Directive (see box below) provides consumers with comparative information on the relative energy efficiency of appliances at the point of purchase.

Figure 7 EC Energy Label

By law, the European Community Energy Label must be displayed on all new household products of the following types displayed for sale, hire or hire-purchase:

- Refrigerators, freezers and fridge-freezer combinations
- Washing machines
- Electric tumble dryers
- Combined washer-dryers
- Dishwashers
- Lamps
- Electric ovens
- Air conditioners

Mail Order catalogues, Internet advertisements and manufacturers' literature must contain similar information. Individuals will be provided with this information wherever they buy or hire these products.

'A' rated products are the most efficient and 'G' rated products the least efficient. The most efficient fridges and freezers can now be identified by new 'A+' and 'A++' markings on the large black arrow appearing against the green 'A' arrow.

This scheme currently excludes consumer electronics and information communications technology (ICT) products, but efficient ICT products can be identified by the voluntary ENERGY STAR endorsement (currently under review) which originated in the US but is now becoming an international standard.

The European scheme is generally accepted to have been success, but has recently received growing amounts of criticism and is currently under review. Issues relating to the current scheme include:

- Labelling has been a victim of its own success with 'crowding' in the A rating. Whilst the labelling scheme has driven manufacturers to achieve A ratings, now that the majority appliances for sale are A rated there is little differentiation. (ANEC, 2008)

- Self certification can result in wider variations in test results due to test environment (Sluis, 2000).

- Testing methods have been criticised for being unrealistic, for example fridge tests do not involve opening the door (Morretti, 2000).

- Low sales of A+ and A++, rating refrigerators suggest that either these higher bands are not effective at influencing behaviour, or that A sales are largely due to the crowding mentioned above. Experience in other countries suggests that top rating do tend to stick in peoples minds (Australian experience).

- The use of 'rolling' standards whereby as average standards improve, rating bands improve, would address the above concerns, but this is resisted by manufacturers as it would require retesting which poses additional costs.

The appliance manufacturer organisation CECED has proposed an open ended scale using numbers from one upwards (CECED, 2007). However, it appears that an adaptation of the current letter rating scheme is more likely given the public's recognition of it (ANEC, 2008).

Perhaps the greatest achievement relating to the labelling scheme to date is that it allowed for the identification and regulation of the least efficient appliances. If the labelling scheme is to continue to be a driver for efficiency then it is argued that there needs to be competition for the best grades. One way to promote continual improvement is to introduce 'rolling' standards without the need for appliance retesting is to base grades on kWh e.g. kWh/wash etc. The standards could then be derived from metric data gathered during past tests.

Schemes such as the EST Energy Saving Recommended (ESR) voluntary labelling programme that only endorses the top 20% of the market within a particular product group are more flexible and may be more effective at driving innovation. They supplement rather than replace mandatory labelling as it is important that information on the energy consumption of all appliances is available to consumers at the point of purchase.

Whilst appliance ratings give an impression of relative efficiency there little information on the importance of how appliances are used in practise. For example cold appliance energy demand increases if:

- they are not defrosted;

- the temperatures are set unnecessarily low;

- the appliance is situated in a warm environment;

- there is restricted air flow to the heat exchanger;

- the heat exchanger gets dusty; or

- if warm food is not left to cool before loading.

In summary for all appliances there appears to be an opportunity for benefits from information on optimal location, maintenance and operation. In addition, the rating only refers to efficiency not total consumption e.g. large efficient fridge can get good rating but could still be consuming a lot of energy unnecessarily.

For ICT equipment the ENERGY STAR label provides customers with some indication of efficiency but mandatory minimum standards are the best approach to guarantee carbon savings. Analysis by the MTP shows limited adoption of operating system energy efficiency settings; there is scope to make these the mandatory default setting. All machines could be automatically shipped in the lowest energy mode, with suitable guidance, providing low cost demand and education benefits.

8.5.3 Better billing and metering

'Better billing and metering' is a programme across Great Britain which aims to provide householders with better information on household energy consumption. The expectation is that this will drive changes in behaviour and conserve energy. The policy was first announced in 2006 and was developed further in the 2007 Energy White Paper. It is, in part, a response to the requirements of the ESD, which requires the promotion of Better Billing and Metering.

In its response to consultation, published in April 2008, the Government announced its decision to go ahead with better billing from January 2009 from which point it will be mandatory to provide historic information in energy bills (OPSI, 2008b)[90]. Smart metering could offer a cost effective way of gathering the accurate data required to comply with the Regulation. However, rather than opt for a mandatory approach to display devices, the Government has agreed to voluntary arrangements with gas and electricity suppliers on a limited 'free' offer.

According to the NAO (2008), estimated savings must be considered very uncertain until the evidence base improves. Current Government estimates of savings are based on experience in other countries.

The Energy Demand Reduction Pilot (EDRP) run by Ofgem (for BERR) looks at what changes energy use, by how much and for how long. It consists of a series of trials on:

- Initiatives with existing metering e.g. benchmark bills, displays, advice measures;
- Remotely read meters;
- Smart meters including a visual display unit; and
- Time of use tariffs.

The trials will provide information on reductions in energy use that consumers make in response to different forms of feedback about energy usage and will test consumer response to time of use tariffs that encourage energy use to be switched away from peak periods (DTI, 2007) The EDRP is designed to provide and strengthen the evidence base for government policy makers (Ofgem, 2006).

8.6 Improved energy efficiency of products

8.6.1 Eco-Design of Energy Using Products EU Directive

This aims to reduce energy use of products used in the domestic sector. It establishes an EU framework under which manufacturers of energy-using products will, at the design stage, be obliged to reduce the energy consumption and other negative environmental impacts occurring throughout the product life cycle. In the

90 This means that energy bills will in future contain some information on historic consumption but it will be in the format of the energy suppliers choosing.

UK the Directive is implemented via the Eco-design of Energy Using Products Regulations.

The Directive makes provision for the introduction of so-called Implementing Measures, which can be minimum energy performance standards (MEPS) or other mechanisms. All energy using products sold in the domestic sectors are potentially covered by the new Directive[91]. There is forthcoming EU legislation on 20 different product areas[92] as part of the EU Energy Using Products Directive. This Directive includes legislation on stand-by which could significantly reduce energy consumption (see below). It also includes three other Implementing Measures (one for each of set-top boxes, tertiary lighting and power supply units) which have now been approved at Regulatory Committee and are at the same stage as the stand-by Implementing Measure.

It is difficult to estimate the impact this policy will have on energy consumption. This depends on the way the Directive is implemented and enforced in the UK.

(Draft) Commission Regulation on stand-by

On July 7 2008, delegates of the EU Member States and European Commission (EC) endorsed a proposal for a regulation (under the EU Energy Using Products Directive) reducing so-called stand-by power consumption in household and office products. Once approved by the EU Parliament, the new regulations on electronic devices will take effect from 2010.

According to the Regulation, there will be a maximum allowed power consumption in stand-by mode of no more than 1W in computers, washing machines, TVs, and other office and household devices as of the year 2010. If the devices have a display, the maximum may be increased to 2W. The admissible levels will be halved three years later.

The EC expects a reduction in electricity used for stand-by of 73% by 2020 for the whole of the EU (Europa Press Releases Rapid 2008). How much of this will be achieved in the UK depends on the level of enforcement and changes in future legislation. The increasing number of set-top boxes, which are recommended to be on stand-by all the time, might diminish the effect of the regulation.

8.7 Microgeneration

Microgeneration policies sit within wider renewables policy (driven by the Renewable Obligation and EU Renewables Directive).

8.7.1 Microgeneration Strategy

The strategy was launched in 2006 with the objective of creating the conditions under which microgeneration becomes a realistic alternative or supplementary

91 Except for all means of transport which are covered by other legislation.

92 The twenty product categories are: boilers and combi-boilers; water heaters; personal computers; imaging equipment; consumer electronics; stand-by and off-mode losses of EuPs; battery chargers and external power supplies; office lighting; street lighting; residential room conditioning appliances; electric motors/water pumps/circulators in buildings; commercial refrigerators and freezers; domestic refrigerators and freezers; domestic dishwashers and washing machines; simple convertor boxes for digital television; domestic lighting; complex set top boxes; solid fuel small combustion installations; vacuum cleaners and laundry driers. Source: MTP http://www.mtprog.com/cms/eup/

energy generation source for the householder, the community and small business. The Strategy is not a regulation itself but sets the framework for a range of different regulations.

8.7.2 Low Carbon Building Programme

The BERR Low Carbon Buildings Programme (LCBP) provides grants for microgeneration technologies for householders, community organisations, schools, the public sector and businesses. Phase 1 of the programme is managed by the Energy Saving Trust and Phase 2 of the programme is managed by BRE.

Launched on 1 April 2006, the programme will run over three years. The programme is UK-wide (apart from the Channel Islands and the Isle of Man) and will demonstrate how energy efficiency and microgeneration will work hand in hand to create low carbon buildings.

Two streams of grants are available:

- Stream 1 - these grants apply to smaller projects for home owners.
- Stream 2 - these grants apply to medium and large scale microgeneration projects and are available to public, not for profit and commercial organisations.

The technologies covered by the LCBP are listed in the table below.

Table 11 Technologies covered by the LCBP

Bio-energy	Small hydro
Fuel cells	Solar photovoltaics (PV)
Ground source heat pumps (GHSP)	Solar thermal hot water
MicroCHP (Combined heat and power)	Water/air source heat pumps
Renewable CHP	Wind turbines

8.7.3 Renewables Obligation (RO)

The Renewables Obligation (RO) is a Government initiative to encourage more renewable electricity generation by placing an obligation on suppliers to sources a certain proportion of their energy from renewables.

The scheme operates by allocating electronic certificate to eligible generation; one certificate, known as a Renewable Obligation Certificate (ROC), is issued for each megawatt hour (MWh) of renewable electricity generated. Electricity suppliers need these certificates to meet their obligation under the scheme. The certificate can be traded separate from the energy and so suppliers can buy certificates from each other and third parties. ROCs can provide a significant additional income stream to renewable generators.

Although the administrative burden of receiving a ROC may householders that only generate small volumes of renewable energy off participation in the scheme, there is no minimum threshold level for eligibility.

Achieving the 2010 RO policy target of 10% requires a significant amount of new build per year. This is primarily expected to be large scale generation, but the increased uptake of micro renewables in the domestic sector (and arguably by increased demand for green energy tariffs from households) would assist in meeting the target.

8.7.4 Microgeneration Certification Scheme (MCS)

The Microgeneration Certification Scheme (MCS) aims to increase consumer confidence. It is designed to:

- evaluate products and installers against robust criteria for microgeneration technologies;
- provide greater protection for consumers; and
- ensure that government grant money is spent in an effective manner.

This new scheme will underpin BERR's grant scheme, the Low Carbon Buildings Programme (see above), and grants will be available to applicants using both products and installers certified under MCS or equivalent schemes.

Other initiatives, such as the proposed stamp duty land tax relief for new zero carbon homes, are also expected to use MCS in the future.

8.7.5 Code for Sustainable Homes: Zero Carbon Homes

This code is regulated for by the Building Regulations and Zero Carbon Homes represents Code Level 6. This is the highest level attainable. With time, Government proposes that the minimum code level standard for all new build homes should be bettered (DCLG 2006). For example:

- 2010: Code Level 3 requires a 25% energy/carbon improvement compared to Part L Building Regulations.
- 2013: Code Level 4 requires a 44% improvement.
- 2016: Code Level 6 requires all homes to be zero carbon.

Onsite energy generation is likely to be required in the vast majority of homes built to Code level 6 if the use of offsite generation is capped at below 50%. In the whole of the UK this could result in onsite generation being installed for between 250,000 and 300,000 new homes a year.

However, the UK Green Building Council[93] has put forward a new definition of zero-carbon housing which will factor in the use of off-site renewables. Research results showed that the current definition is 'not achievable on up to 80% of new homes' (UK Green Building Council 2008).

Government has not made a final decision on the definition of zero carbon. It is therefore difficult to estimate the likely impact on microgeneration uptake.

93 The UK-GBC Zero Carbon Task Group was established to review the current definition of ‘Zero Carbon’ as laid out in the Code for Sustainable Homes (CSH) Technical Guidance, and propose amendments where required in order to support effective implementation of Government’s stated targets for zero carbon buildings in the future.

8.8 Policies incentivising electric vehicles

Although there is no explicit overarching transport strategy in place which supports electric vehicles, the uptake of electric vehicles is currently incentivised by e.g. the avoidance of road fuel duty, congestion charging and road tax exemption[94]. In the absence of measures to encourage off-peak charging of these vehicles, there may be an increase in annual and peak electricity demand. The idea that cars could provide energy services such as feeding back energy to the grid at peak demand times (effectively acting as temporary storage) is also being explored (e.g. Rocky Mountain Institute's smart garages project).

Rates of uptake of electricity vehicles are currently relatively low. Transport for London offers a 100% discount on the Congestion Charge[95] for vehicles on the PowerShift register which includes hybrid cars and electric vehicles are also exempt. Around 1,000 electric cars are currently registered for the 100% discount on the congestion charge (GLA 2008).

8.9 Indirect impacts of other policies

The sections above discuss policies which directly impact on energy consumption in the home. There are, however, a range of policies which do not explicitly target energy consumption but indirectly impact on energy use in the home.

- **Improved water efficiency in homes**: policies such as the Code for Sustainable Homes indirectly affect domestic energy consumption through impacting on water consumption. A reduction in hot water consumption leads to a lower domestic energy requirement.

- **Dissemination of information on environmental issues**: increased awareness of environmental issues can have a positive impact on people's behaviour with regard to energy consumption.

8.10 Role of smart metering

Smart metering is not an essential for all of the policies in place but would be beneficial for many of them. For example, understanding how much energy is consumed by different appliances might encourage people to buy more efficient goods and one way of achieving this is through the provision of more timely and accurate information (which could be achieved using smart metering if data is sent to through e.g. a VDU, phone or website).

Smart meters are not a prerequisite for microgeneration however they would provide access to time of use metering, which would facilitate time varying feed-in tariffs. Such tariffs could provide incentives for innovation and adoption in microgeneration to reduce peak demand on the grid.

Given appropriate and open interface standards, the meter could be integrated in to a wider home automation system whereby appliances can respond to price signals

94 Cars which emit less CO2 can benefit from a reduced car road tax. For cars emitting less than 100 g/km the car road tax is reduced to zero.

95 The London Congestion Charge came into force on 17 February 2003 and the tariff was increased on the 4 July 2005. Vehicles travelling into the congestion zone pay £8 per day between 7am and 6pm, Monday to Friday (excluding public holidays).

or the availability of micro-generation.[96] It could also reduce costs for meter reading and ease the payment process.

Policies to address fuel poverty through energy saving could be supported by smart meters. In particular, if consumers were encouraged to use the information that a smart meter provides (e.g. via a visual display unit) they could control their energy expenditure more closely. In addition to providing the information required to change behaviour, smart metering could also allow householders to identify the most cost effective tariff option[97] and to adjust their energy consumption according to time of use tariffs.

The communication of energy consumption or money spent via e.g. visual display units, websites or mobiles phone etc will be key. The Energy White Paper suggests that smart meters with visual display units should be rolled out within ten years. Although visual display units are now proposed to be included in CERT, there is no incentive for suppliers to role out more sophisticated displays which can communicate with smart meters (and therefore allow access to the wider benefits associated with smart meters). One option would be a grading system where suppliers receive higher reduction points for more sophisticated appliances.

For further information on the role of smart metering in delivering energy reductions and load shifting, see section 11.3 below.

8.11 Findings and policy gaps

There is range of policies which tackle energy efficiency in the home. Some of those have been in place for a considerable time (e.g. the Warm Front) whereas other will start to bite in the future (e.g. the EU proposal on stand-by). The key policy impacts identified are summarised in the table below.

Table 12 Summary of impacts of Government activities

Impact on energy demand	Description of impact
Improved energy efficiency in homes by installing measures e.g. Warm Front, Fuel Poverty Action Programme, CERT, landlord energy saving allowance, Decent Homes, reduced VAT on energy saving materials	Reduced energy (electricity and gas) use for heating in households (in the absence of comfort taking)
Improved information on energy efficiency of homes e.g. Energy Performance of Buildings Directive (EPBD), Energy Performance Certificates (EPCs)	Provision of information on energy efficiency of homes Increased awareness of climate change Potential to affect house prices differentials and incentives to install measures (see row above)
Improved information to end users about their own energy use in homes e.g. policy linked to the Directive on Energy End-Use Efficiency and Energy Services (ESD)	Provision of historic information (in graphical form) on energy users' bills Greater awareness of electricity and gas use (Expectation that will) reduce energy use

96 The meter in itself is not able to control anything

97 If users have ready access to detailed information about their energy use, they are in a better position to compare the costs of different tariffs (which may vary depending on the volume and timing of energy demand). Quarterly energy bills provide only a crude basis for comparison of costs.

Impact on energy demand	Description of impact
Greater availability of generic information about domestic sector energy use e.g. ActOnCO2, Climate Change Fund, Energy Saving Trust advice centres	Provision of typical/ average historic information on energy users' bills Greater awareness of how electricity and gas use affects CO2 and reductions by some concerned households
Improved energy efficiency of products e.g. Product ban on incandescent bulbs, Eco-Design of Energy Using Products Directive, EST energy saving recommended scheme	Reduced electricity use (including stand-by power)
Improved information about energy using products e.g. EU Energy Labelling Scheme, Market Transformation Programme	Provision of energy labels and supporting information More informed choice of lower energy consuming appliances (and heating equipment)
Greater uptake of non-renewable microgeneration (combined heat and power, CHP) in homes e.g. Microgeneration Certification Scheme (MCS)	Energy generation on-site at home Reduced electricity import from grid Increased natural gas use.
Other microgeneration (for electricity or heat) e.g. Low Carbon Building Programme (LCBP), feed-in tariffs	Energy generation on-site at home Reduced electricity or gas import from grid
Price signals affecting energy costs e.g. EU ETS, VAT	Higher energy costs and so stronger price signal to reduce energy use
Greater uptake of electric vehicles and plug-in hybrids e.g. road tax, congestion charging, company car tax differentials	Charged up via domestic electricity supply (In the absence of measures to encourage off-peak charging) increase in baseload and peak electricity demand, cars could provide energy services such as back feeding at peak i.e. act like a battery for the house.
Improved water efficiency in homes e.g. Code for Sustainable Homes, Market Transformation Programme	Reduced energy use
Improved and increased waste recycling in homes e.g. EU Landfill Directive, Local Area Agreements	New potential renewable energy supply Increased awareness of climate change (and potentially energy use)

Although existing policies do already encompass multiple measures targeting different areas, there are policy gaps. Some of these are highlighted below.

- **Refurbishment of existing stock:** policies such as the Code for Sustainable Homes and the Building Regulations target new homes. Although other policies do aim to increase the energy efficiency of existing homes, there is still considerable additional potential for energy savings.

- **Lack of incentives to correctly size boilers** – suppliers are not currently incentivised to ensure householders have the right boiler system and operate them properly. This may be resolved through introducing a category on heating systems in Home Information Packs or in the energy audits under CERT.

- **Heating control systems:** heating controls can make the use of boilers etc. more efficient but as things stand, there are limited incentives to install these. For instance, the retrofit of standard heating controls could be promoted more by revising the SAP. Advanced heating controls such as time proportional, chrono proportional controls could also result in significant additional reductions but uptake is currently low and support is limited (indirect).

- **Uncertainty around behaviours:** even where policies are in place to install additional equipment or to improve the functionality of a heating system, energy savings will only optimised if behaviours change. There has been a step up in the level of government activity around information provision and awareness raising in recent years. However, there is yet greater scope to persuade people to change and to help them sustain good behaviour/ maintain interest.

- **Overcoming supply side barriers:** There are a range of (real or perceived) supply side barriers to ensuring the uptake of even cost effective measures. These include a lack of skilled personnel (for installation, operation, maintenance or advice) or a limited R&D in technologies where long-term certainty is required to make that research appear the best use of funds.

- **Lack of integration between physical and behavioural measures** under CERT and other policies: there are limited feedback mechanisms, other than the requirement for historic billing information.

- **Lack of direct rewards for information activities** by suppliers. As noted above, historically policies like CERT have focused on measures like the installation of e.g. cavity wall insulation, rather than some of the tools discussed in this report.

- **Lack of reward for load shifting** by suppliers: this is due to the large number of end-users (and so the large number of households that would need to be influenced to have a significant impact) and the current settlement system which is based on averages for the domestic sector.

9. QUANTIFICATION OF POTENTIAL REDUCTIONS

As part of this project we have reviewed how much additional energy each of these measures can save. The text below sets out our assumptions for three different scenarios of uptake of the tolls discussed, which are drawn from the literature review, our own views and interviewee feedback.

9.1 Scenario overview

We have taken BERR projections as a starting point – the scenario used assumes the full delivery of existing firm and funded energy/ carbon saving policies. Three other scenarios have been developed and modelled.

- **Scenario 1 'Additional Measures'**: this reflects a world where additional policies are put in place to encourage increased uptake of cost effective tools. It reflects the idea that even where savings are cost effective, there may be barriers to their uptake. This scenario has the lowest level of energy savings of the three scenarios but still assumes action above and beyond the full delivery of policies already in place.

- **Scenario 2 'Idealistic'**: this reflects the level of savings that could be achieved if all measures that have a relatively short payback period or that do not have prohibitively high upfront costs are implemented. Achieving this scenario would be even more challenging than either the 'full delivery of existing measures' or the 'Additional Measures' scenarios above.

- **Scenario 3 'Step Change':** this considers the maximum level of energy savings[98] that could be achieved. This would be extremely challenging since it would require not only changes in behaviour, but also the uptake of tools with relatively long payback periods. It assumes that measures deliver their full technical potential.

The text below presents the assumptions behind each of these. All of the measures described relate to what can happen over and above those measures that are already incentivised and included in the BERR projection of business as usual e.g. via CERT. Further details of the methodology and assumptions used in the modelling can be found in Appendix 3.

9.1.1 'Step Change' scenario

The 'Step Change' scenario is designed to achieve the maximum level of savings over time. This involves using both state of the art technologies and also affecting dramatic behavioural change. It therefore assumes that:

- financial constraints to energy savings and management are lifted i.e. even tools that are not cost effective today are introduced;

- barriers to delivering behavioural change are largely overcome i.e. the whole population is motivated to act;

- every household is made as energy efficient as possible (even where that household is not an ideal candidate for measures e.g. where retrofitting is required);

98 Energy rather than carbon savings. The increased uptake of renewables could help reduce carbon. In addition fuel switching could also reduce carbon.

- appliances and systems are replaced before the end of their lifetimes if a more efficient model is available;
- not only do consumers install the most efficient system/ appliance available, they also use it optimally (note thought, that it may be still be oversized[99]);
- non-essential energy use is reduced e.g. watching less TV and/ or reducing the number of appliances.

These are strong assumptions. The aim is to give an idea of the maximum potential from the types of measure considered in this report in an 'ideal' world. We have applied a number of conservative assumptions around those listed above.

- The savings quantified are calculated assuming the most efficient models available now.
  - The advantage of this approach is that it allows us to draw on data that is readily available to calculate the savings. In fact, we would expect technical innovation over the period to introduce more efficient appliances onto the market.
- There is no fuel switching other than move to solar thermal and GSHP i.e. homes that are currently heated using electricity, coal or oil do not switch to natural gas.
- The only Step Changes in the way that energy is used are positive ones (i.e. they result in energy savings).
  - We could envisage a world where a new activity actually results in an increase (e.g. like say the rapid proliferation of MP3 players or set-top boxes witnessed recently). This effect could effectively balance any gains from innovation.
- There is some uptake of heat pumps.
  - Domestic heating could be supplied by a range of renewable technologies, from biomass boilers to geothermal or micro CHP[100]. Although it does not impact on the volume of energy that a household uses, it does impact on the carbon emissions from that energy use.
  - GSHP and air source heat pumps (ASHP) use electricity to operate, but deliver around 3-4 units of heat per unit electricity use[101]. They can be used to service a range of heat loads and do not have the same fuel supply issues that, say, biomass may have. GSHP also avoid concerns around noise, but do require some space to install the heat collectors.
  - For the purposes of this scenario, in the interests of simplicity, we have assumed that renewable space heating is provided by a single technology, GSHP. This results in an increase in electricity use, is which is offset in carbon terms by a reduction in fossil fuel use for heating.

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99 See section 5.2 on space heating.

100 Micro CHP is considered outside the scope of this study.

101 There is a number of Air Source Heat Pump listed with a Coefficient of Performance (COP) in excess of 3.4 under the Enhanced Capital Allowance scheme see www.eca.gov.uk.

- Additional savings in new build (rather than the existing building stock) are only those included by BERR in the business as usual scenarios.
  - It could be the case that all new build homes are as efficient as possible and are orientated to maximise solar gain. They could have: passive heating; maximised or minimised solar gain using blind controls; passive ventilation; heat exchangers etc. Every new build could have a larder which would significantly reduce the use of cold appliances.
- Some behavioural steps that would have a considerable impact on lifestyle are not taken up.
  - Hot water: in theory everyone could have a shower not a bath with a low flow rate (no power showers) and could reduce time to 5 minutes.
  - Wet appliances: small households could all wash up using a bowl, while larger households use state of the art machine that sprays on water.
- Lighting reductions are restricted to more efficient bulbs automation and behavioural change.

Table 13 Description of 'Step Change' Scenario by energy end use

Final energy use	Description
Space Heating – existing homes	1) Fabric, boiler and pipes: every existing home is insulated as far as is technically possible. e.g. all homes that have cavity walls have cavity wall insulation; loft insulation and pipe insulation are also introduced in existing homes; even expensive options (such as solid wall insulation) are taken up to maximise the efficiency of the current building stock. 2) Heat supply: renewable heat generation is used in some households and homes that do not use renewables use the most efficient condensing boiler available on the market (run on natural gas). All old and inefficient boilers are replaced by 2010. 3) Heating control: every home has the most advanced heating control system which automates optimum use of the heating system and can save up to 25% of space heating. 4) Awareness and behaviour change: people set programmers to an 'eco-setting' or turn down their thermostat so that the target temperature is 1^{o}C below current levels.
Water heating	Solar thermal systems replace an increasing proportion of the current water heating systems (uptake is assumed to peak in 2020 at just over 50%). The remainder is generated using condensing boilers run on natural gas.
Cooking	In all houses, only the most efficient cooking appliance in its category is used[102]. Households switch from electric hobs to microwaves for up to 20% of their cooking[103]. People also change the way they cook (e.g. use lids on pans etc) which results in energy savings of 15% across all appliances for cooking.
ICT (computers, faxes, modems, printers etc.)	Only the most efficient equipment available on the market is used by 2020 and overall numbers of equipment are minimised (e.g. average of one computer/ monitor per home).

102 Based on delivered kWh of heat/primary input

103 MTP estimate that around 20% of cooking could be done more efficiently if in a microwave (MTP, 2008b).

Final energy use	Description
Consumer electronics (TV, DVD player, Digi-box, Games consoles etc.)	Only the most efficient equipment available on the market is used by 2020 and overall numbers of items are minimised (e.g. average of one TV per home). Operation times are halved as people are motivated to reduce their energy use.
Cold appliances	Everyone has best available model by 2020 (A++). The models perform to their deign specification. Installers are trained to site appliances optimally and users are made aware of maintenance and operation issues.
Wet appliances	Only 10% of the number of tumble driers used in 2006 remains in 2020 because households switch to line drying. All households have best in class appliances. Everyone washes at 40°C on a full load.
Lighting	Everyone has the most efficient light bulbs available on market for all light fittings.
Stand-by	Stand-by is reduced to zero for all appliances except set-top boxes. Stand-by of set-top boxes is minimised to the bare minimum requirement.

9.1.2 'Idealistic' scenario

The aim of this scenario is to describe a world with significant, but lower energy savings. It still assumes that barriers to making 'rational' or cost effective decisions are overcome, but unlike the Step Change scenario, the Idealistic scenario rules out measures that would have a long payback period[104]. However, we do still assume in some cases that individuals will incur accelerated depreciation i.e. replace their equipment/ appliances before the end of their natural lifetime (we note where current replacement rates are assumed instead below).

Table 14 Description of 'Idealistic' scenario by energy end use

Final energy use	Description
Space Heating – existing homes	1) Fabric: all insulation with a payback of 5 years or less is assumed as cost-effective and therefore taken up by householders (BERR, 2002). Cavity wall insulation is assumed as cost effective for all dwellings apart from flats (EST, 2006). Loft and boiler insulation is cost-effective. Solid wall (internal and external) insulation are assumed not to be cost effective. 2) Heat supply: no uptake of GSHP and solar thermal. All homes use most efficient condensing boilers by 2010. 3) Control: all heating controls replaced from 2010 so that all have modern standard controls by 2020 (assumed to generate 17% of savings in energy consumption). Additionally, people use current systems better and reduce target temperature by 1°C.
Water heating	As Step Change scenario
Cooking	As Step Change scenario
ICT (Computers, faxes, modems, printers etc)	As Step Change scenario, except assume replacement rates of equipment is same as now.

104 Anything that has a payback period of more than 5 years is assumed not to be 'cost effective'. We have taken payback periods from published sources.

Final energy use	Description
Consumer electronics (TV, DVD player, Digi-box, Games consoles etc)	As Step Change scenario, except assume replacement rates of equipment is same as now.
Cold appliances	As Step Change scenario, except assume replacement rates of equipment is same as now.
Wet appliances	As Step Change scenario, except assume replacement rates of equipment is same as now.
Lighting	As Step Change scenario
Stand-by	Reduction in stand-by through efficient appliances in accordance with the EU Ecodesign Regulatory Committee proposed regulation on stand-by consumption of appliances (Europa, 2008). Additionally, people switch off all appliances (except set top boxes) from 2010.

9.1.3 'Additional Measures' scenario

This scenario takes into account the fact that even if energy saving and behavioural measures are cost effective there may be barriers to their uptake. Such barriers from the perspective of the demand side, i.e. the actual energy user, include[105]:

- inertia: householders may be reluctant to change from the status quo;
- lack of interest: even if individuals do know how they could save energy, they may see no benefits in doing so;
- lack of awareness: individuals may not be aware of the impact that their activities have on energy use or of the opportunities available to address them;
- lack of knowledge: it may be that individuals find it difficult (or at least, time consuming) to find out how exactly they could implement energy savings and of the fact that they are indeed cost-effective;
- hassle: fitting new appliances takes time for search, installation and potentially learning for operation. Even though the actual costs in terms of time may be small, individuals may perceive costs to be higher and this in itself can act as a barrier to uptake;
- limited availability of equipment: when energy saving measures are at the design stage, they may only be available in sufficient numbers for a field trial rather than mass distribution.

This scenario therefore takes these barriers into account and aims to present what might realistically be delivered from the implementation of the measures discussed above. Although this scenario reflects a lower level of uptake of measures than in the Step Change or cost-effective scenarios, a considerable amount of support and awareness-raising will still be required to achieve the reductions modelled.

105 Many of these barriers also bite on the demand side.

Table 15 Description of 'Additional Measures' scenario by energy end use

Final energy use	Description
Space Heating – existing homes	1) Fabric: uptake of insulation measures (beyond levels projected under firm and funded policies) is restricted to the most environmentally aware section of the population (18% (Defra 2008a)) as the majority of the population is not aware and not willing to consider these measures. 2) Heat supply: no uptake of GSHP and solar thermal. All homes use most efficient condensing boilers – these are replaced when they become inefficient. Replacement rate of boilers stays constant – all condensing (included in full delivery of existing policies scenario). 3) Control: replacement rate of heating control increases slightly – driven by CERT and energy awareness of the most environmentally aware people. Some people (e.g. more environmentally aware) turn down heat by 1^{o}C but majority of people keep same/increase comfort levels.
Water heating	Remains constant (no additional uptake of solar thermal beyond full delivery of existing policies).
Cooking	Remains constant for all appliances except electric ovens. The replacement rate of electric ovens remains constant but people only buy A, A+ or A++ due to increased awareness of energy consumption.
ICT (Computers, faxes, modems, printers etc)	Goes up in line with full delivery of existing policies projection (which assumes advances in efficiency but increase in usage).
Consumer electronics (TV, DVD player, Digi-box, Games consoles etc)	Goes up in line with full delivery of existing policies projection (which assumes advances in efficiency but increase in usage).
Cold appliances	Appliance replacement rate remains constant but people only buy A, A+ or A++ due to increased awareness of energy consumption of cold appliances. Typical efficiencies are assumed to be 10% below design spec as people continue to operate/maintain them in same way.
Wet appliances	Appliance replacement rate remains constant but people only buy A, A+ or A++ due to increased awareness of energy consumption of wet appliances. Typical efficiencies are assumed 10% below design spec as people continue to operate/maintain them in same way.
Lighting	Replacement of energy efficient lighting according to normal replacement rate of light bulbs. Negligible amounts of automation and behavioural change.
Stand-by	Savings only from proposed EU regulation - achieves 73% reduction of stand-by by 2020. In addition, the most environmentally aware segment of the population (18% of the population) switch off equipment when not needed.

9.2 Energy use projections

The chart below summarises the energy demand (electricity and gas[106]) projected under each scenario. Energy demand (gas and electricity) under the full delivery of

106 Includes reduction in gas consumption due to uptake of solar thermal and GSHP

existing policies scenario is projected to decrease by approximately 76.4TWh from 2010 to 2020 due to a number of firm and funded policies[107].

For the three scenarios modelled we have assumed that the first year in which reductions can practically be achieved is 2010. A modest decline, up to 31TWh, in demand is shown under the Additional Measures scenario (Scenario 1). The Idealistic scenario (Scenario 2) shows a steeper reduction in demand of up to 115TWh in 2020 compared to the full delivery of existing policies scenario. Under the Step Change scenario (Scenario 3), reductions in energy demand are substantial from the first year and their rate increases over time (in 2020, projected energy demand is only 199TWh, a reduction of 198TWh from the full delivery of existing policies projection).

Further details of the contribution of different measures to this total saving are provided in Appendix 4.

Figure 8 Energy (gas and electricity) demand under each scenario

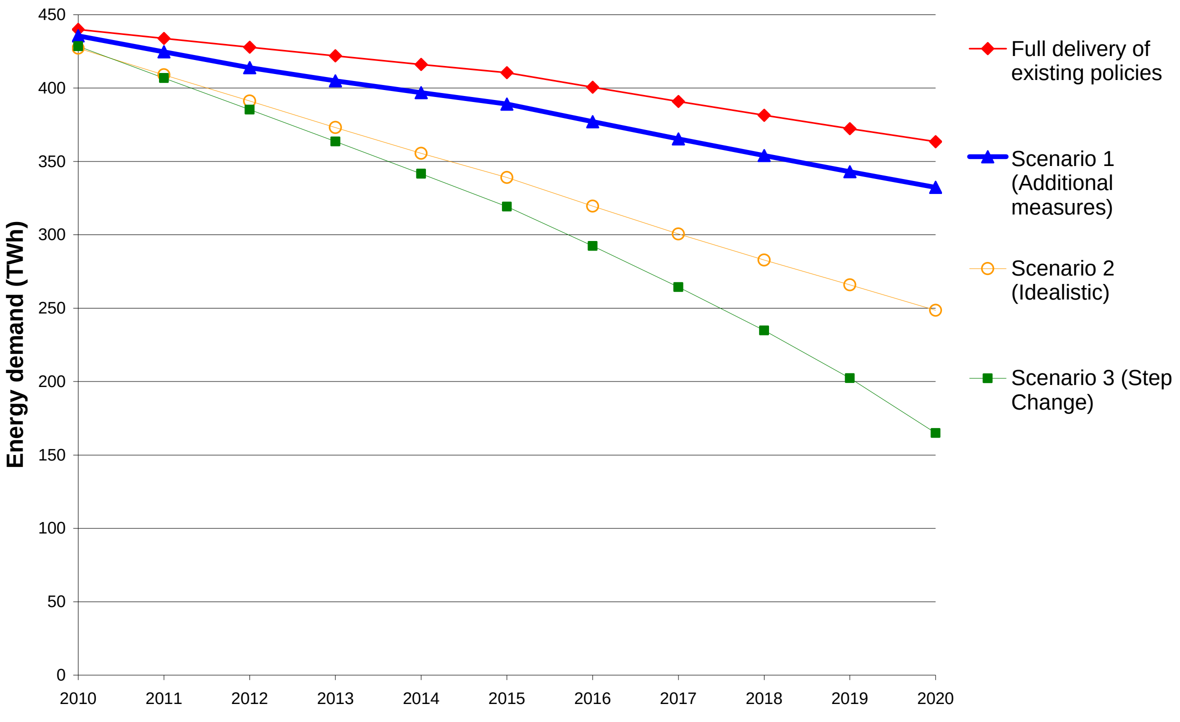


Table 16 sets out the annual electricity and gas savings achieved under the three scenarios, both relative to the full implementation of existing policies scenario and to 2010 levels.

107 Excluding the future Supplier Obligation.

Table 16 Annual electricity and gas savings in 2020

Scenario	TWh reduction per year from full implementation of existing policies	TWh reduction from 2010 consumption figures
Scenario 1 (Additional Measures)	31 (9%)	108 (24%)
Scenario 2 (Idealistic)	115 (32%)	191 (43%)
Scenario 3 (Step Change)	198 (55%)	275 (62%)

This compares to the UK target for energy efficiency in the domestic sector (set in the Housing Act 2004), aims to improve residential energy efficiency by at least 20% by 2010 from a year 2000 baseline. Given it is not yet certain, the extension to CERT and future Supplier Obligation(s) (SO) is not included in the full delivery of existing policies scenario; the table below compares the reduction in electricity and gas consumption with the savings projected under the CERT extension and SO.

Table 17 Savings from the implementation of each scenario and the extension to CERT and future Supplier Obligation

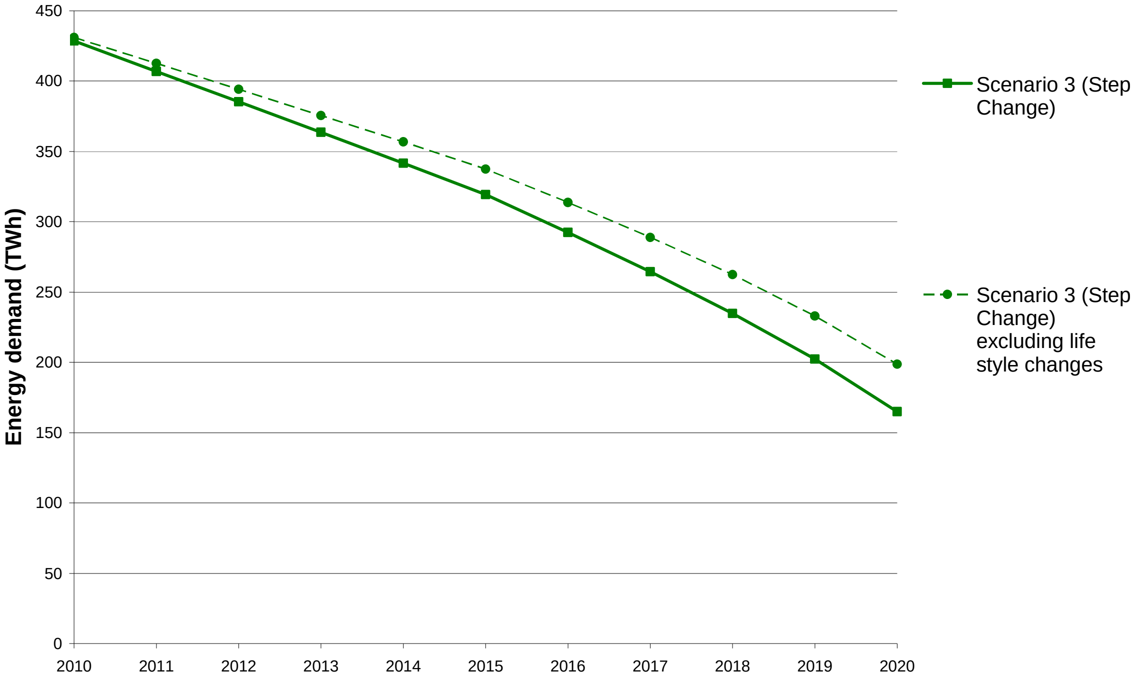
Policy/scenario	Annual gas and electricity saving (TWh/year)	% from full implementation of existing policies
Extension to CERT	2	1%
Supplier obligation	27	7%
Scenario 1	31	9%
Scenario 2	115	32%
Scenario 3	198	55%

Given that the scenarios combine a combination of behavioural measures, technological uptake and lifestyle change we have split out the magnitude of the impact below[108]. The first chart shows projected energy demand under the Step Change (Scenario 3) scenario excluding life-style changes [109]. It shows that behavioural and lifestyle change is responsible for around 17% of the total reduction seen in 2020 in the Step Change scenario.

108 The scenarios also include some uptake of renewables. However, the assumptions have a very limited impact on energy *use*, the greatest impact of the renewable assumptions is the reduction in carbon emissions that they result in.

109 Lifestyle changes refer to reductions in comfort e.g. by turning thermostat down or reductions in activities e.g. watching less TV. Behaviour change refers to actions that increase efficiency but do not change the nature of the service or product e.g. cooking with pan lid on.

Figure 9 Step change scenario energy use project excluding lifestyle change



The pie charts below show the contribution of the different measures to delivering the energy (gas and electricity) savings in 2020 (compared to the full delivery of existing policy scenario) for the three scenarios. Behavioural responses (both those defined as small behaviour change and as lifestyle changes) are separated out into their own category and include the following actions:

- Turning off stand-by;
- Turning thermostat down or setting heating controls to a lower target temperature
- Reducing the number of appliances and operation times
- Reducing use/eliminating tumble driers
- Cooking more efficiently
- Switching some cooking to microwaves

The other categories represent technological measures only.

It can be seen that behavioural measures account for only 2% of the reductions in the Additional Measures scenario but this rises to 6% and 17% in the Idealistic and Step Change scenarios (respectively). The majority of the savings from technical measures in the additional scenario come from technical stand-by reduction and energy efficient lighting. Insulation[110] and better heating controls are also important. It can be seen that in order to get to the Idealistic and Step Change scenarios it will

110 In the Additional Measures scenario insulation savings refer to the level of insulation expected to be achieved by existing policies plus the most environmentally aware section of the population (18% (Defra 2008a)) installs all insulation that has a pay back of under 5 years.

take contributions from a diverse range of technical measures accompanied by behavioural change.

Figure 10 Split of energy savings by measure for Additional Measures (2020)

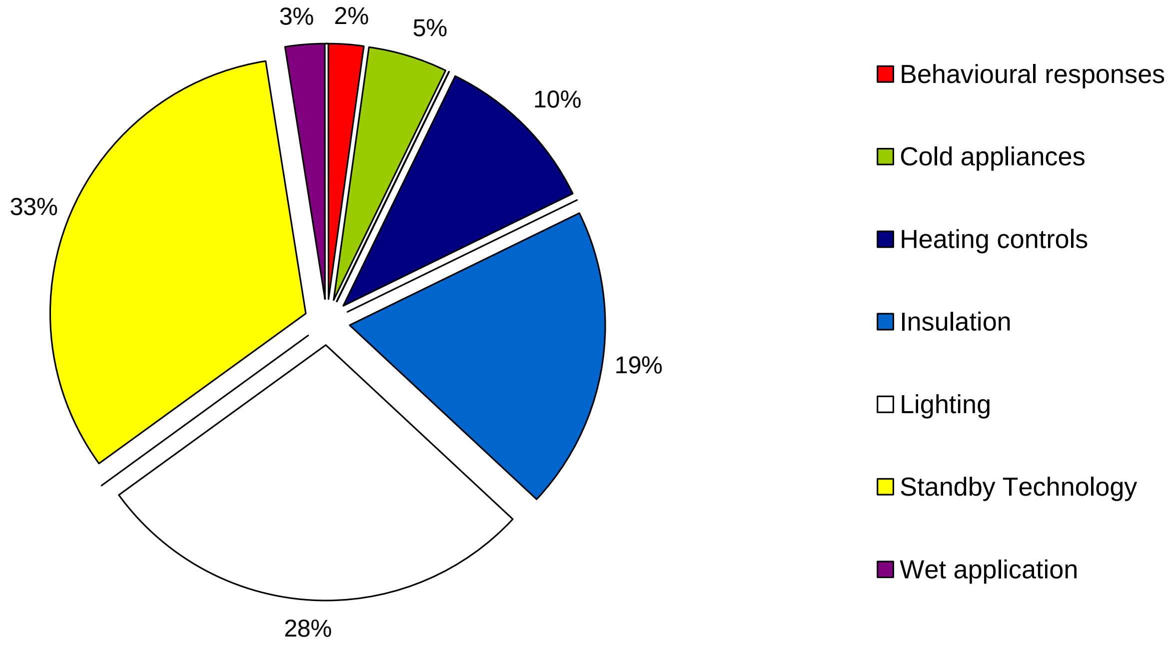


Figure 11 Split of energy savings by measure for Idealistic (2020)

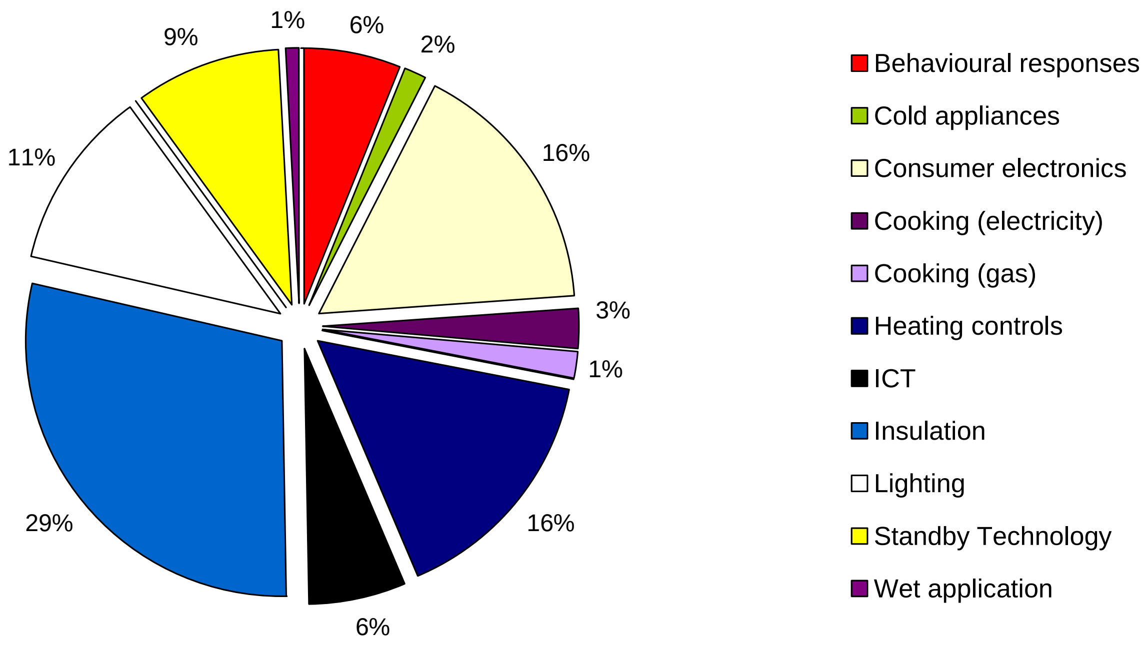
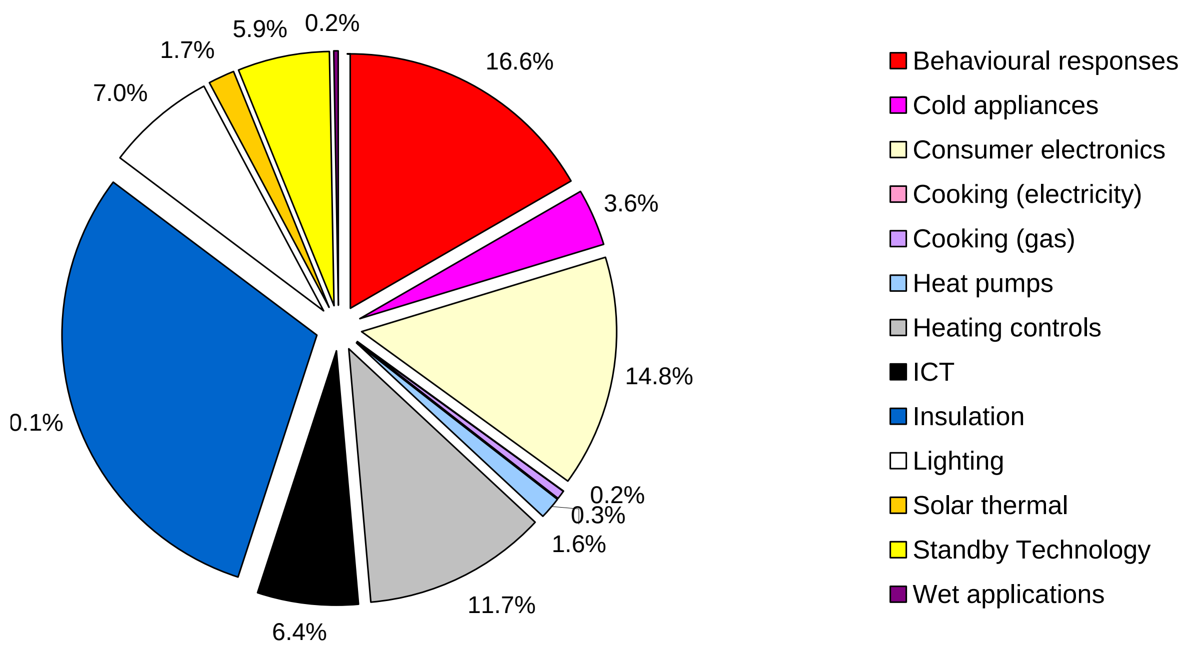


Figure 12 Split of energy savings by measure for Step Change (2020)



9.3 Carbon reduction projections

The chart below shows the projected carbon emissions under full delivery of existing policies and under each of the three scenarios modelled. Overall, carbon emissions decline, but not to the same extent as the energy trajectory. This is because the carbon emissions factor for gas (0.19kgCO_2/kWh) is substantially lower than that for electricity (0.43kgCO2/kWh) (IAG, 2008); therefore reductions in gas have a lower overall impact than that of electricity on carbon emissions.

The overall reduction in emissions from full implementation of existing policies projected in 2020 for Step change (Scenario 3) is 55MtCO_2, for the Idealistic (Scenario 2) 36MtCO_2, and for the Additional Measures (Scenario 1) 11MtCO_2.

Figure 13 Carbon emissions (MtCO_2) projected under each scenario for the years 2010-2020

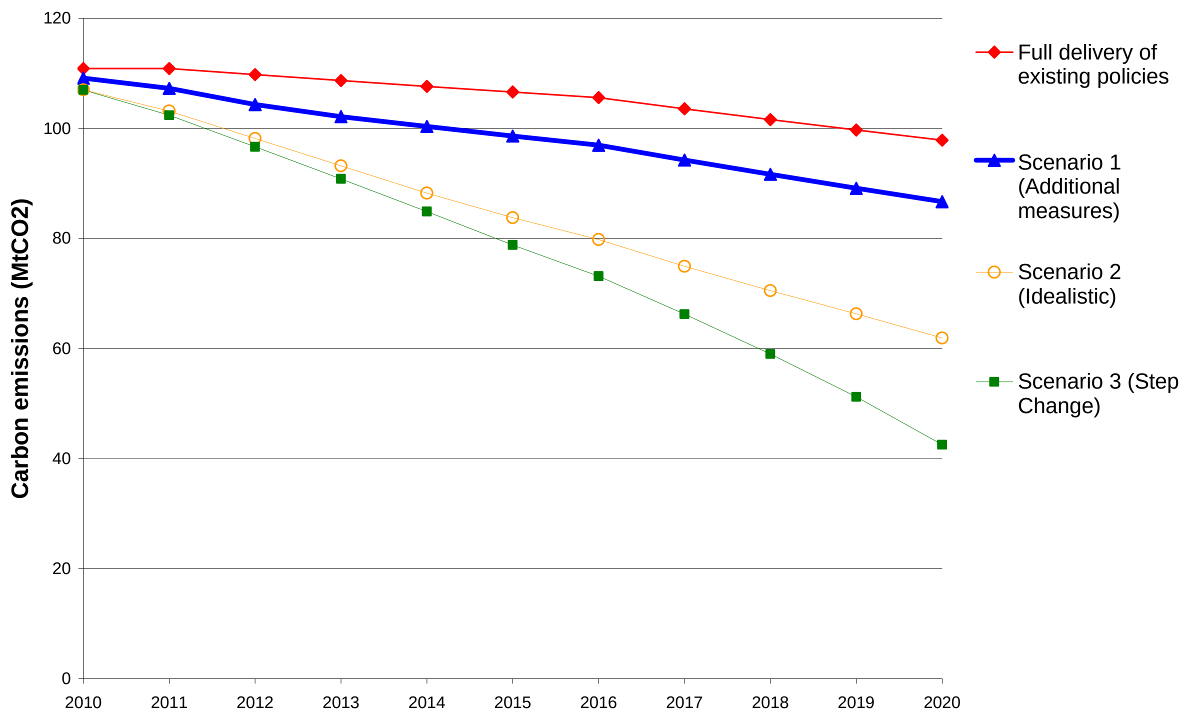


Table 18 shows the annual carbon savings achieved under the three scenarios, both relative to the full implementation of existing policies scenario and to 2010 levels.

Table 18 Annual carbon savings (MtCO_2) in 2020

Scenario	MtCO_2 reduction per year from full implementation of existing policies	MtCO_2 reduction from 2010 consumption figures
Scenario 1 (Additional Measures)	11 (11%)	20 (22%)
Scenario 2 (Idealistic)	36 (37%)	45 (44%)
Scenario 3 (Step Change)	55 (57%)	64 (62%)

It should be noted that these estimates do not take account of the so-called rebound effect where reductions in cost and/or time may lead to people increasing carbon emissions elsewhere. A study by the UK Energy Research Centre (UKERC) splits the rebound effect into two types:

- direct (e.g. driving further in a fuel-efficient car); and
- indirect (e.g. spending the money saved on heating on an overseas holiday).

The study suggests that direct rebound effects can be considerable - less than 30% for households for example. Much less is known about indirect effects. However, the study suggests that in some cases, particularly where energy efficiency significantly decreases the cost of production of energy intensive goods, rebounds may be larger.

To avoid energy use increases undermining the benefits to climate policy, UKERC recommends building 'headroom' into policy targets to allow for rebound effects, raising energy prices in line with energy efficiency improvements or imposing absolute caps on emissions (UKERC, 2007)

9.3.1 Overview of results

A summary of the emissions reductions projected under each scenario is provided in the table below. Under all three scenarios reductions in emissions are primarily due to decreases in electricity consumption. Almost all of the emissions reductions for Scenario 1 are driven by electricity (9 out of 11$MtCO_2$). In Scenario 2, electricity accounts for 70% of the 36$MtCO_2$ emissions reduction. In Scenario 3, the contribution of gas to the total of 55$MtCO_2$ emissions reduction increases to 43%.

Table 19 Emissions reductions ($MtCO_s$) per year under each scenario for the years 2010, 2015 and 2020 compared to emissions under full implementation of existing policies

Scenario	Fuel	2010	2013	2015	2020
Scenario 1 (Additional Measures)	Gas	0.1	0.6	1.0	1.8
	Electricity	1.7	5.9	7.0	9.4
	Total	**1.7**	**6.6**	**8.0**	**11.2**
Scenario 2 (Idealistic)	Gas	1.3	4.3	6.3	10.6
	Electricity	2.5	11.2	16.6	25.3
	Total	**3.9**	**15.5**	**22.8**	**36.0**
Scenario 3 (Step change)	Gas	0.8	5.7	9.1	23.8
	Electricity	3.1	12.1	18.7	31.6
	Total	**3.9**	**17.9**	**27.8**	**55.3**

The key sources of the annual savings in Scenario 3 in 2020 are as follows.

Table 20 Top 10 sources of energy saving in 'Step Change' scenario

Measure	Change on full delivery of existing policies		
	% change in energy	TWh reduction per year	$MtCO_2$ reduction per year
Consumer electronics	19%	28.6	12.3
Insulation	19%	28.5	5.4
Heating controls	17%	25.9	4.9
Behavioural responses	10%	15.2	2.9
Lighting	8%	12.8	5.5
ICT	8%	12.3	5.3
Wet applications	5%	7.9	3.4
Cold appliances	4%	6.5	2.8
Solar thermal	4%	6.1	1.3
Cooking (electricity)	2%	3.0	1.3

9.4 Uncertainty around the projections

The projections provided above depend on the assumptions made, and particularly on the assumptions around: changes in behaviour, the number of electric appliances (especially consumer electronics and ICT) and the number of times an appliance is used per year. The details are provided in an Appendix to this report.

We have not undertaken any statistical analysis to establish where our projections fall within the range of possible outcomes. However, we have sense checked them against other published sources, and consider them reasonable.

In all our scenarios we assumed one or more forms of behavioural change. Some assumptions are ambitious given the status quo (for example our assumptions on stand-by), while others are (relatively) conservative (such as our assumptions on cooking with microwave ovens). As highlighted throughout this report, one of the inherent features of behaviour is that it can change, for apparently irrational reasons.

For the calculation of electricity consumption by electronic appliances we have made assumptions on the number of appliances used. Future penetration rates of electronic appliances are uncertain; for simplicity we have either assumed that the current stock remains constant or that it decreases to a minimum (non-zero) level. In reality, for some appliances (e.g. consumer electronics) the number of appliances in use might increase in the future. Similarly, our assumptions for how often an appliance is used are based on data which relates to current use levels. This may change in future (particularly in the type of world described in the last section of the report).

It is also worth highlighting that none of our scenarios consider technical innovation. This means that, on the one hand our calculated reductions are rather conservative. On the other hand, one could argue that new appliances will be developed which consume a lot more energy than current ones. A good example is the recent increase of energy consuming flat screen TVs.

Finally, we have not factored in that although an appliance is expected to consume a certain amount of energy, misuse of appliances might result in higher energy consumption. For example, end users might leave fridge doors open or put heating systems in place which are not well maintained.

10. SUPPLY SIDE IMPACTS

By optimising the amount, type and timing of energy used in the home, some of the measures described above can also have an impact on energy supply (both electricity and gas). If the penetration of any of these measures is significant and is not offset by other factors, then these impacts would need to be accommodated by the energy supply chain[111].

10.1 Overview of impacts identified

The supply-side impacts that we have identified are as follows:

- **Reduced annual demand:** energy savings measures reduce the total volume of energy (either electricity or gas) required over the particular year. This can result in reduced use of more expensive energy sources and so a reduction in the number of units of energy sold. It can change projections of energy demand and so the amount of new generation capacity required.

- **Fuel switching:** measures that encourage fuel switching e.g. from electric heating to gas, may result in an increase in demand for a particular type of fuel at a particular location, even if there is a net reduction in the total volume of fuel required overall.

- **Peak load reduction:** measures that shift the time at which energy is used may not reduce the amount of energy required in a year, but instead can shift demand and so influence the level of peak demand.

  - This may allow peak electricity generation to be used less often, so displacing more expensive and carbon intensive energy sources. Peaking plant (e.g. OCGTs) can be more carbon intensive than baseload plant (as a result their efficiency, or their reliance on more carbon intensive fuels like oil, or both)[112].

  - Energy networks and generation capacity are designed to ensure security of supply during annual peak demand periods (winter in the UK). If the change in demand profile is sustained over the long term, it may affect the capacity required to service peak demand and so affect the nature and amount of investment required.

- **Reduced network demand and reduced losses:** the uptake of microgeneration that is embedded in the distribution network will reduce a household’s electricity import from the network and may also reduce its gas imports[113]. It may also (depending on the household’s demand profile and how the equipment is sized) result in electricity exports to the network. This affects the volume of electricity that needs to be generated by transmission connected plant/ serviced by the gas transmission system, and can also reduce transmission and distribution losses.

- **Network management:** Introducing initiatives that allow domestic sector demand to be more closely measured, monitored and controlled provide

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111 From fuel supply to energy generation, transmission, distribution and retail.

112 This project has not involved detailed modelling of the carbon intensity of electricity and gas provision at peak.

113 Increased uptake of gas-fired micro-CHP would increase gas demand.

significant scope to better manager the electricity (and gas) networks. This could reduce costs and potentially carbon emissions[114].

- **Data availability:** In addition to informing the end-user, the collection of better (i.e. more detailed, accurate and timely) data on energy use can also have benefits for third parties such as suppliers and grid operators. It may allow for markets to operate more efficiently, e.g. via more innovative tariff offerings and opportunities for advanced grid management.

10.2 Role of demand side management in managing energy supply

Whilst there is some demand side participation in the industrial and commercial sectors, the domestic sector is almost entirely isolated from active participation in the electricity or gas markets. Demand side measures targeted at the domestic sector have historically been focussed on ‘fit and forget’ static measures such as thermal insulation and more recently compact fluorescent lights (CFLs). These measures save energy without any change in consumer behaviour and as such can be considered passive.

It is widely recognised that even a modest demand response can have positive effects on moderating extremes in wholesale prices, by reducing pressure on the system at peak. This both helps to avoid using expensive energy sources and also helps to ensure security of supply. There are three broad categories of demand response activities (Hirst and Kirby, 2001):

- load shifting incentivised e.g. by time-varying pricing;
- interruptible and voluntary load reductions;
- customer provision of ancillary services (e.g. dynamic demand control).

These measures can be used alone or in combination. Typically energy users are rewarded for delivering one of these activities through a reduction in their energy bill (e.g. through a bonus payment or avoiding a (very) higher per unit price at peak times).

10.3 Impacts on supply side

The scenarios described in Section 9.1 above show the volume of energy that the domestic sector could save in a particular year (see Appendix 4 for detailed outputs). The impact that this could have on the time and location of energy use will also impact on the supply side. In the table below we highlight the key supply side impacts or the ‘Step Change’ which has the largest impact of all three scenarios.

114 In the US the promotion of ‘smart grid’ technology which optimises the electricity network by managing both demand and supply has become Federal Government policy (see section 10.5 below).

Table 21 Overview of supply side impacts

Fuel	Demand-side impact	Impact on supply side
Gas	Reduction in annual gas demand	Where fixed costs (e.g. infrastructural costs) are recovered through average charging across annual consumption, a reduction in the number of units consumed will result in higher per unit costs.
		The extent to which compressors and other energy-using equipment need to be used to move gas around the network will be affected, as will network losses. Whether this is a positive or negative change (in terms of energy use, carbon emissions and cost) depends on how the location of gas demand relative to its entry points into the UK is affected[115].
	Reduction in peak day gas demand	The capacity of the gas network is managed to ensure security of supply on the peak day. If domestic sector savings of gas at peak are sustained in the long term, this may result in a lower investment requirement and so reduced costs.
		In the short-term, lower peak demand, may allow more expensive gas sources e.g. storage or LNG to be avoided.
	Increased control over gas demand at peak	Interruptible contracts are used for large industrial companies/ power stations, to manage demand at peak. This helps to dampen prices and ensure security of supply. For the domestic sector to be able to deliver similar benefits for demand management, it would require many more users, that non-essential loads could be isolated and subsequently turned off with some certainty (e.g. even if the householder was not at home).
Electricity	Reduction in annual electricity demand	As for gas, lower annual sales would mean that fixed costs (e.g. of generation and infrastructure assets) would need to be spread across a smaller volume and so could be higher on a per unit basis.
		Transmissions and distribution losses may also be affected, but as for gas, the nature and magnitude of the change from an annual reduction will depend on where geographically those changes are made, and also on the time of day, week and year they are achieved[116].

115 Given that gas compressors are covered by the EU ETS, some would argue that an decrease in their use in the UK would simply free up emissions allowances for other energy intensive activities in the EU and so would not result in an overall decrease in carbon emissions.

116 As is the case for natural gas, power generators are covered by the EU ETS, so some would argue that reduced UK power sector emissions results in an offsetting increase in CO2 emissions elsewhere in Europe and therefore would not result in an overall decrease in carbon emissions.

Fuel	Demand-side impact	Impact on supply side
	Reduction in peak electricity demand	The electricity network and generation capacity is maintained to ensure security of supply in the highest demand period of the year. Reduced peak demand could reduce the investment required and so costs.
		It may also result in avoiding calling on peak plant (which are typically less efficient and use more carbon intensive fuels). The extent of any supply side impact will also depend on whether peak demand is reduced through energy saving or load shifting[117].
		Reduced peak demand may also reduce transmission and distribution losses[118]. Since losses obey the I^2R law[119], they are much more significant at times of peak. This means that at peak, a considerable amount of energy is wasted, in effect heating cables and transformers. Reducing peak demand therefore has the potential to have a greater impact than reducing average demand.
	Increased control over electricity demand at peak	Being able to control the demand load (remotely) could help to better manage the network and so to reduce costs and ensure security of supply. As for gas, the scale of the savings will depend on the extent to which those savings can be guaranteed.

10.3.1 Potential for load shifting in the UK

Compared to the US, the UK has less domestic air conditioning, thus to some extent less potential for load shifting. In addition a large number of consumers in the UK (over 20%) are already on an Economy 7 tariff which means that there is limited further potential for shifting electric space and water heating.

However, there may be potential to load shift some wet goods using automation or time of use tariffs[120] and cold appliances for limited periods. Whilst householders may want to continue to use certain appliances e.g. electronic goods and lights at peak times there may be some load shifting opportunities for these types of appliances if there are sufficiently strong price signals.

In the absence of smart metering it is not possible to know exactly when demand occurs or to reward customers for load shifting. The introduction of time of use tariffs may also require some changes in the balancing and settlement system, so

117 Based on Government Guidance, the same emissions factor (representing energy displaced from the long-run marginal gas fired plant) is used regardless of time of use. As a result, load shifting is not considered to deliver a carbon benefit in such an appraisal, whereas, in reality, this carbon saving will fluctuate depending on the marginal plant, losses, and the need for spinning reserve.

118 Losses account for around 7% of all electricity generated, of which 1-2% are associated with transmission system and 5-6% are associated with the distribution system. Total losses in 2007 were 6.6% (BERR, 2008b).

119 Losses are equal to the square of the current multiplied by the resistance.

120 There may however be cases where the operation of wet goods off peak may create a nuisance due to the noise.

that it reflects actual demand data instead of the existing profile classes (but commentary in the debate indicates that these implications are modest.[121]

The financial savings from reduced peak may be partially offset by the increased administrative and computing costs resulting from more complex tariffs. However much of these costs will be upfront costs and should not present major operational costs once systems are up and running (data volumes may be relatively modest but dependant on tariff specifics).

Given that the mechanisms described are common in the commercial and industrial sectors, the main barriers to achieving improved demand response in the domestic sector relate to the issues seen in the smart metering debate. For example meter ownership, stranded assets and interoperability standards.

10.3.2 Quantification of the potential for peak electricity demand reductions

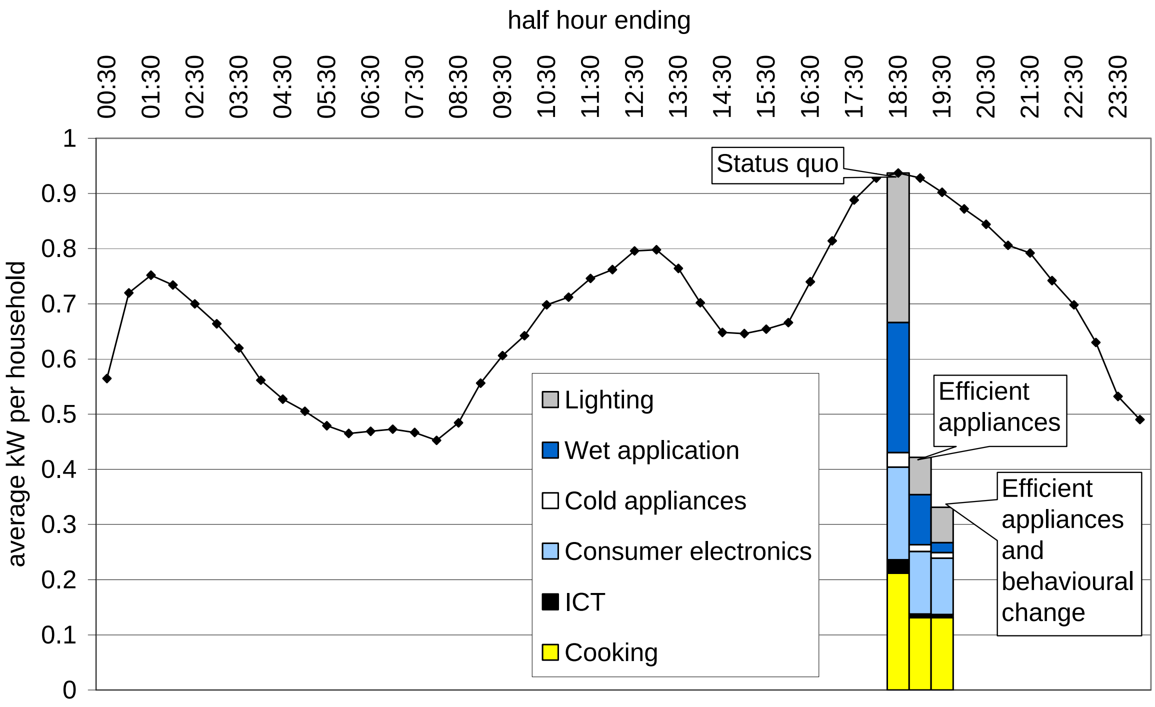
In order to estimate the potential for reducing peak electricity demand from the domestic sector in the UK, two elements were considered:

- the reduction in load possible: i.e. reduction in demand due to the implementation of the most efficient appliance/ goods available to reduce demand;
- the shift in the peak demand possible: due to behavioural measures (such as TOU tariffs) and technological measures (e.g. direct switching) to move the time of demand.

By making a series of assumptions about the measures that could be achieved in the Step Change scenarios, the potential demand reduction shown in the table below was calculated. It illustrates how average peak energy demand per household could be reduced by 45% from 0.94kW to 0.42kW through the introduction of energy efficient appliances, and by a further 0.09kW by avoiding energy use at peak. This reflects a total decrease in peak energy use of nearly two thirds[122]. Based on these assumptions, reduced energy use in the half hour alone could deliver around 3.08MtCO2 per year[123].

121 Personal communication with Mark Bilton.
122 Further details around the assumptions used are provided in Appendix 5.
123 Assuming the long run marginal grid electricity emissions factor of 0.43kgCO2/kWh

Table 22 Potential impact of energy efficient appliances and behavioural measures on peak demand



Note: Columns all relate to peak hour.

It is important to consider what time of day the load will be moved to. If demand is only shifted by a small amount of time, this will be less useful from a supply side perspective, than if it could, say, move evening demand to overnight. Efforts to load shift focus on two areas: smoothing the evening peak (through TOU tariffs) and directing customers to use energy at particularly lower demand periods e.g. weekday afternoons through automatic controls on appliances.

The relative merits of the load shifting will depend on the generation mix and may therefore change over time. Given a move towards intermittent renewables, in future there may be significant benefits associated with shifting demand to periods where supply may exceed demand e.g. a windy summer midday.

Data requirements for load shifting

As noted above, more detailed, timely and accurate information on demand levels can be used in combination with flexible tariffs so that customers know to reduce their consumption during peak periods. They can allow energy suppliers to encourage end users to actively manage their demand.

Table 23 Energy and carbon saving measures by energy suppliers

Aim	Type	Sub-type	Examples
Provide consumers with information on electricity prices to	Interpreted data on electricity market	Incoming alert during peak demand periods	Ambient Energy Orb

Aim	Type	Sub-type	Examples
prompt and inform changes in energy use	Information from supplier	Information on tariff price at a particular time	Visual Display Units (VDU) Smart meters Key meters/key-pad meters (e.g. in Ireland)

The communication of interpreted data via a VDU or website aims to inform users of the cost of use at a particular time and so to prompt reductions at peak. As discussed above whilst load control technology can be facilitated in the absence of smart metering, if participation is optional then metering is required to reward participants.

There have been trials of an Ambient Energy Orb in California which glows different colours depending on the load on the electricity system. *"The orb flashes during the two hours before a 'critical peak' with high unit costs, and users who tried it out tended to reduce consumption well in advance of the peak and to continue with the reduction for some time afterwards. As a consequence, there was some overall saving as well as load-shifting".* A study of 120 users showed savings of 40% (Martinex and Geltz, 2005).

10.4 Impact of microgeneration

The small scale generation of heat or electricity (microgeneration) can be considered as a demand side measure when it is connected to the network since it affects the volume and timing of demand that needs to be met by centralised generation. It can have the following impacts on domestic sector energy use.

Renewable generation (excluding heat pumps):

- reduced annual demand for either electricity or gas for heating from the networks;
- reduced peak demand for either electricity or gas for heating from the network; and
- reduced carbon intensity of energy use.

Gas-fired CHP[124] and heat pumps (ground source or air source):

- although gas-fired CHP may reduce (annual and peak) grid electricity demand, it could increase a household's demand for natural gas; and
- heat pumps are powered by electricity and therefore will increase a household's electricity use (this increase in energy consumption should be more than offset by the reduction in heating fuel imports that they deliver).

There is also some evidence that microgeneration can reduce the net amount of electricity consumed as it increases awareness of energy consumption, particularly

124 Although currently in research and development, micro CHP may offer potential to reduce peak load since there is a strong correlation between heat and electricity demand. For example winter evening see highest electricity peak with need for heating.

if there is a monitoring system that allows for the amount of electricity imported/exported to be viewed.

The magnitude of the impact on the supply side will depend on:

- how the generation is sized and how well it is matched to the household energy load (i.e. what proportion of a household's demand can be met);
- the generation's characteristics (e.g. PV operates when demand is lowest and thus will only have off-peak benefits. Wind powered generation, although intermittent, does provide increased output during cold seasons so may benefit peak, although its availability cannot be guaranteed);
- the extent to which it is automated or other appliances in the house are automated to operate with it; and
- whether it is connected for export and so services the demand of others too (primarily a consideration for electricity-only generation and CHP).

10.4.1 Data requirements for microgeneration

The current situation with microgeneration is:

- Either no additional meter is used and so energy is spilled onto the local network without measurement and payment is based on estimated output.
    - Good Energy uses this approach, on the basis that metering costs would be prohibitive. As an incentive to use meters, the generator is paid the value of their ROC (which can be considerable) if it has its own meter.
- Alternatively, the supplier fits a special meter that counts incoming and outgoing energy flows on a separate register. Outgoing units are then bought by the supplier (the rate will depend on the contract specifics but will typically reflect the wholesale market price in some way).

Although the export of microgeneration is possible in the absence of smart metering, improved data captured could help to manage the grid more effectively, particularly if microgeneration levels increase in future. The main benefit would be that it could facilitate time varying feed-in tariffs, which could provide incentives for innovation and adoption in microgeneration that can operate at peak.

Moreover the advent of viable electrical storage could allow microgeneration to provide services to the system when they are most valuable. As with critical peak demand reduction, real-time alerts could be used to request microgeneration in times of supply scarcity or local network congestion.

The use of smart meters might help microgenerators access ROCs as they could be used to send export data to suppliers or Virtual Power Plant (VPP) operators (see below).

"*To get ROCs generators need a separate meter per microgeneration technology, a box that summates the data from the meters which is then fed to a smart meter which transmits data to supplier*". (EdF Interview)

10.5 Electricity network evolution and innovation

The move to increased renewable penetration and decentralized power generation poses new challenges for the UK's electricity networks which have traditionally been highly centralised. For example, the recent growth of wind generation has seen the connection of significant levels of generation connected to networks not specifically designed to accommodate intermittency. Existing networks were essentially designed for power flow in one direction; from the national grid, down through the distribution networks to the consumer.

The current situation may result in relatively high connection costs for microgeneration or higher use of system charges than would otherwise be the case. It may also mean that access to the network to export power is limited, either in that a connection agreement is not available or that the optimal capacity cannot be obtained. This can mean that energy from microgeneration must be consumed locally and cannot be sold for distribution offsite via the network. In the UK, domestic microgeneration does not yet pose a problem, since the installed capacity is low, but this may change in future as the penetration of distributed generation increases.

There is expected to be a significant increase in the amount of wind generation. The UK has committed to generating 15% of all energy from renewables by 2020. Wind is expected to make a significant contribution to the target and may be needed to produce as much as 36% of total electricity generation by 2020 (compared to around 4% now) (BERR). Due to the unpredictability of wind output there will be increasing value in the ability to load shift in order to reduce the amount of expensive standing reserve required. Real-time pricing that is updated half-hourly may be increasingly useful to increase the flexibility in demand.

These and other concerns have given rise to consideration of how existing electrical networks can be adapted to facilitate future energy scenarios. In particular interest in the concept of 'Smart Grids' and 'Virtual Power Plants' has been growing.

Smart grids

'Smart grids' refer to electricity systems where resources and services can be co-ordinated more efficiently through the use of information and communications technology. Smart grids break from the centralized tradition by harnessing the capabilities of a broader set of actors and technology, including those on the demand-side and local storage.

A 'smart grid' is a transformed electricity transmission and distribution network or that uses robust two-way communications, advanced sensors, and distributed computers to improve the efficiency, reliability and safety of power delivery and use.

Smart Grids use demand side management (DSM) to reduce peak consumption, help facilitate the grid connection of distributed microgeneration, and provide grid energy storage for distributed generation load balancing and improved reliability against many different component failure scenarios.

The term 'Smart Grid' originates from the US and the promotion of Smart Grid technology is now policy under the Energy Independence and Security Act of 2007. Smart Grids are also being developed in the EU.

Virtual Power Plants

The operation of small scale generators can be coordinated to provide services traditionally provided by centralised power stations. This concept can also be broadened to include load control and electrical storage systems.

A 'Virtual Power Plant' aggregates a portfolio of decentralised generation (potentially including microgeneration) and controls loads throughout the distribution network. A VPP could trade as a conventional power plant and receive ROCs for renewable generation across its portfolio which would reduce the administrative burden.

One of the main benefits of a VPP is the ability for rapid frequency response which is becoming increasingly useful as intermittent capacity increases. Domestic customers could sign up to and agree to have a number of appliances remotely controlled to enable operator to control loads (EdF Energy Networks Interview).

10.5.1 Data requirements

A move to smart grids or VPPs would require the installation of smart meters as it would require two-way communication between consumers and (depending on the approach used) suppliers/ grid operators. The Virtual Power Plant is perhaps one of the more advanced applications of smart metering with advanced meter management (AMM) functionality, but this does not mean that enabling the AMM meter need be especially complex.

Instead, given the appropriate level of functionality, smart meters can facilitate support for a wide spectrum of services. This highlights the importance of ensuring that any metering technology installed, as well as being interoperable, has a feature set adequate for future energy system scenarios.

SECTION 3: ACHIEVING THOSE REDUCTIONS AND LONG TERM OUTLOOK

11. DELIVERING THE REDUCTIONS

The Additional Measures scenario modelled (see Section 9) provides one view of the level of energy savings that could be delivered given the current technologies available. It assumes that there are many barriers to the uptake of cost effective options. Delivering even the energy savings shown in this Scenario requires some action on the part of the domestic sector.

To move towards the higher levels of energy reduction shown in the Idealistic it would be necessary to overcome some additional barriers to uptake witnessed at the moment. These barriers can include hidden and missing costs as well as the above-average costs that may be incurred where the optimal application of a measure is not possible[125]. Moving even further, to the Step Change scenario, would require that the financial barriers to measures that currently have a payback of longer than 5 years[126] also be overcome.

It is unlikely that any single policy measure or government intervention could achieve these aims (interviewees agreed that a package of measures is required). Potential measures range from awareness campaigns to financial incentives. In this section we review what the barriers to uptake are and how they might be addressed. It considers the tools and incentives for networks, suppliers and consumers required to achieve to the Additional Measures scenario. It considers what could be built into existing Government policies and also considers how reductions may be delivered from other actors such as community groups.

11.1 Amendments to existing policies

11.1.1 Carbon Emissions Reduction Target

CERT is expected to play a key part in delivering energy savings from the domestic sector whilst reducing fuel poverty. As things stand Government expects CERT to deliver about 15.76 TWh/year (9.8 TWh/year of gas and 4 TWh of electricity and the rest coming from oil and coal) by 2020[127]. There is scope to achieve additional savings under this framework.

The advantages of targeting suppliers to deliver energy savings in the domestic sector are clear, although there is an inherent contradiction in asking any retailer to sell less of its product. However, there is evidence, from energy saving tariffs now available, that there may be some incentive to do so in a competitive market. It is worth noting that network operators currently charge for the service of operating the grid (independently from the volume of energy delivered) and may have an interest in improved load management, including via increasing energy efficiency if it has a positive impact on their operational costs[128].

125 For instance, it may be that it is cost effective to install an appliance in new build, or the majority of houses but not in all of them.

126 We have used this threshold to determine whether a measure should be included in the Idealistic scenario or not.

127 Communication from Defra. There will be additional savings from future Supplier Obligations within this period.

128 How this affects the DNO will depend on how it is regulated i.e. whether price controls are such that cost savings are passed back to the business.

Scope for modification

A number of measures have been recently included into CERT including visual display units and energy audits. The way in which they are introduced and the reductions attributed to them will be a key determinant of the extent to which suppliers choose these rather than other actions.

Many of the measures discussed in this report (such as increased feedback to consumers) may result in behavioural change. The integration of behavioural measures into CERT raises a number of issues:

- *Measuring impact*: Monitoring emission reductions and ascertaining the effectiveness of behavioural measures will be challenging – attributing savings separately to the behavioural and technological components of a measure is widely recognised as a difficult task.[129]
- *Short lifetimes*: Targets for CERT are based on lifetime emission reductions and savings for the installation of renewables or insulation may be counted over their technical lifetimes. Based on the literature, behavioural changes typically have a much shorter impact and it is hard to quantify.[130]
- *Calculating carbon savings resulting from demand side management*: Carbon savings under CERT are calculated using an average grid electricity emissions factors. Any behavioural measures that reduced peak demand but do not reduce overall electricity consumption would not therefore be eligible for credits under CERT.
- *Double counting*: The energy and carbon savings resulting from energy audits and energy efficiency advice may result from a combination of both technological fixes and behavioural change. Care must be taken to ensure that suppliers do not receive credit for both the savings resulting from the installation of new technology twice.
- *Additionality*: It is recognised that it is difficult to prove that certain behavioural measures would not have happened in absence of the intervention by the supplier.

11.1.2 Building Regulations and Code for Sustainable Homes

Both Building Regulations and the Code for Sustainable Homes is an important driver to increase the energy efficiency of new homes. There is some concern hat non-compliance may undermine the effectiveness of Building Regulations, especially as they become increasingly stringent (NAO 2008). In order to deliver the savings expected, industry requires support to enable housing developers to meet the increasing standards for energy efficiency.

Similarly to energy performance certificate (EPCs), the code rating of a home could influence purchasing decisions and incentivise more energy efficient homes. There might be scope to link the information provision via EPCs and the Code for Sustainable Homes.

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129 Defra is currently developing a statistical 'data framework' tool to estimate savings from energy efficiency measures. A pilot trial in the residential sector will start in January. See: http://www.defra.gov.uk/environment/climatechange/uk/energy/energyservices/documents/workshop-framework-notes-200608.pdf

130 However if the measures result in permanent behavioural change there might result in savings over a longer period.

The current SAP rating may not sufficiently reflect the benefits of retrofitting heating controls and does not recognise advanced heating controls as time proportional, chrono-proportional controls which could result in significant savings. Work is underway however to reassess the rating the controls receive under SAP.

The major limitation of the building Regulations is that it targets mainly new homes which only cover a small proportion of the overall housing stock. If substantial energy savings are going to be achieved the existing housing stock needs to be targeted as well. For example, with every major refurbishment a home could be required to comply with a minimum standard.

If the regulations covered 'consequential works' the principle would apply to the whole of the existing building, not just the thermal elements as it is at the moment. Furthermore, a threshold expenditure could be specified for example an additional 10% of the project budget should be spent on cost effective energy saving improvements (Killip, 2008).

11.1.3 Energy Performance Certificates

EPCs apply to housing that is being built, sold, or rented to a new tenant, so miss householders who stay in their homes for long periods, meaning that a large proportion of homes will not receive an EPC for the foreseeable future (some of the drawbacks are discussed further in Section 8.3.2).

Theoretically all houses could be required to have an EPC by a certain date regardless of any changes in occupation. Another option might be to push the impact EPCs can have by linking the rating to stamp duty (E.On Interview).

EPC are only the first step; to maximise the savings from the introduction of EPCs it will be important to ensure that people are provided with sufficient mobilising information so that they can act on recommendations.

11.2 Tackling existing housing stock

In order to generate substantial savings in energy consumption the existing housing stock needs to be targeted specifically.

As an example, Germany has recently launched policies which are aimed at increasing energy efficiency of existing homes (Warren 2008):

- Householders are able to take out low-interest loans for measures that help older properties reach new-build standard through refurbishment. Upon achieving such standards, the Government will repay 5% of the loan to the householder. If carbon emissions after refurbishment are 30% lower than minimum new-build standard, 12.5% is repaid. If carbon emissions are halved compared to new-build, 20% is repaid.

Additionally, there is a subsidy scheme which runs in parallel to the loans on offer (although the two cannot be combined):

- 10% of refurbishment costs (up to €5,000) are granted per dwelling achieving new-build standard emissions;
- 17.5% of costs (up to €8,750) if building regulations are improved by 30%;

- 5% (up to €2,500) for undertaking any of the refurbishment packages even if new-build standards aren't quite met.

Total funds for the whole package are about €2.6bn.

Alternatively to grants and loans, the Government could set standards which all existing homes will have to reach by a certain date. It could also differentiate council tax according to energy efficiency of a home.

Softer measures include an increased roll out of energy audits and guidance for end users as well as encouraging the use of community websites.

11.3 Role of Smart Meters

Smart metering is not an essential for all of the policies in place or to encourage the uptake of the measures identified but it would facilitate, and potential enhance, the savings delivered by many of them. The research above highlighted a number of benefits from smart meters such as:

- increased feedback leads to energy savings;
- smart meters are required for demand side management;
- smart meters can provide facilitate time of use tariffs;
- smart meters are beneficial for microgeneration; and
- distributors can benefit from smart meters through better grid management.

The figure below illustrates how smart meters can be used in conjunction with information and awareness raising approaches to change behaviours and to incentivise reductions in energy use. As an example, it then sets out how combining a smart meter with a real time display (RTD) could affect energy use. Lastly it shows the impact that combination with additional tools (smart plugs or appliances) could have.

Table 24 Illustration of potential role of smart metering when combined with other tools

	Technology	Energy and/or carbon savings achieved by
1	Smart meter	More frequent bills for electricity and gas e.g. monthly
		Historic comparisons of energy consumption on bills
		Comparisons with ‘norms’ or benchmarks on bills
		Advice from energy supplier or other third party based on analysis of energy use
		Increased use of pay-as-you-go tariffs
		Websites to see more detailed graphs etc of individual consumption
		Time-of-use tariffs to shift demand

	Technology	Energy and/or carbon savings achieved by
2	Smart meter + RTD	Real-time information on electricity use
		Daily cumulative data on gas use
		Alerts if consumption exceeds thresholds
		Social networking sites to share info and compete
		Alerts about microgeneration output to prompt use of appliances
3	Smart meter + smart plugs or smart appliances + RTD	Detailed consumption information about individual appliances
		Appliances automatically disconnected by the supplier at peak
		Touch screen control of appliances to switch them on/ off

Note that the combinations shown in the table above are cumulative, that is the third option could in principle result in all of the outcomes listed. It is also not exhaustive; for instance, smart meters could also be used in conjunction with e.g. energy audits or heating controls to deliver savings in other ways.

As stated above, smart metering is not an essential for all of the policies in place but would be beneficial for many of them. For example, understanding how much energy is consumed by different appliances might encourage people to buy more efficient goods and one way of achieving this is through the provision of more timely and accurate information. However, the smart meter alone would not deliver these changes particularly not if its display is not easy to interpret and it is not in a prominent position in the home. Key to affecting choices and decisions is communicating the information, which could be achieved using smart metering if data is sent to through e.g. a VDU, phone or website.

11.3.1 Data collection

Depending on the purpose for which data is being collected and the individual involved, consideration should be given to;

- the resolution of data recorded;
- the recipient of the data collected
- and the possible outcomes from the provision of that data,

Half hourly data is the standard resolution used in electricity retail, but for the purposes of audit type analysis higher time resolution and reactive power readings would allow deeper insight into how a home is using energy. In this respect some ‘clip-on’ technologies, like the Wattson are leading the way with resolution down to 3 seconds.

The behavioural benefits of smart metering are not accrued by simply fitting the meter. The meter facilities repeatable communication events (through billing, VDU or email etc) that shape understanding, attitude and behaviour over time. Thus the success of a meter will be determined by the accuracy and interconnectivity of the technology and the motivation, methods and persistence of the empowered actors.

Beyond peak demand reduction, TOU import and export tariffs allow better alignment of micro-generation technologies with supply costs. This would, for example, provide a positive price signal to the developers of and adopter of CHP where heat and electricity correlate when wholesale electricity prices are high (winter evenings).

All the benefits mentioned have an additional dividend of ‘incidental’ learning through social interactions. This should not be discounted, since as described social cues are powerful drivers and meter data would provide a solid factual foundation for these communication events (consistent with current community based energy reduction schemes)

Some argue that the most effective way to introduce smart meters to the domestic sector is a mandatory roll-out. This would ensure that there is sufficient market size to benefit from economies of scale and shared learning. It could also help to ensure minimum technical standards and (to an extent) future proofing. Others argue that smart meters should only be given to those that want them to avoid waste and feelings of intrusion.

11.3.2 Technical requirements for Smart Meters

Key features that any domestic meter would need to exhibit to deliver the maximum benefits identified above include:

- Interface facilitating remote display units that provide direct consumer feedback where the customer can readily see it, and that is presented in a way that engages the household; This same interface could be used to load historic data to PC allowing analysis by software or third-party (e.g. website)

- Advanced meter management (AMM) functionality to allow for access to all the benefits mentioned above (including flexible tariffs), allowing tariffs to appropriately reflect the evolving dynamics of the supply side.

- Being flexible enough to integrate with new technology developments[131] since the roll-out process will take a number of years and associated technology will continue to evolve

Displays can provide a common platform for presenting information on all utilities; electricity, gas, and water. There is a wide range of ways to present the date; there is a common requirement for communication between the actual meters and any display technology. If an appropriate standard is agreed for in home communications, then this would allow integration of appliances and heating systems into a broader system providing information and control. [132]

In addition, ownership of the data is crucial; in addition to information being available to the householder, some of the measures require that energy suppliers and other third parties also be allowed access to the information. We would expect that who has access to the information would be at the discretion of the energy user.

Other considerations are around who installs and owns the meter and who has access to the data. In our view, there are strong arguments for the data generated to owned by the occupant, and for it to be made readily accessible to third parties including, but not limited to suppliers at the discretion of the occupant.

The main focus of smart metering is for electricity however gas smart metering technology is being developed. However, according to BERR (2007b) it is not clear

131 For example they should be able to communicate with appliances in a Home Area Network.
132 An important distinction here is between, the 'legal metrology' that is the meters themselves, which must be accurate, robust and functionally identical, and the 'consumer electronics' such as display devices and home control systems which can be specific to customer type and fail without risk to the wider system.

that the benefits of time-of-use information for gas, which is used for space heating, water heating or cooking, would be analogous to those for electricity. There are fewer benefits associated with changing the time of use of gas. Heating may be better controlled via advanced heating controls than though behavioural change as a result of increased feedback.[133]

According to the Energy Retail Association (ERA) gas smart meters need to include the following features to maximise benefits (ERA, 2007):

- Capable of remote disabling of gas supply and provide for the remote enabling the gas supply through the use of a valve.

- Two way communication which allows the supplier to read the meter and control the mode of operation.

However this would give suppliers the ability to remotely disconnect customers could have a detrimental impact on vulnerable households.

As discussed above, although visual display units have now been included in CERT, there is no incentive for suppliers to roll out more sophisticated displays. It is important that any meters installed by suppliers under CERT can communicate with smart meters in future (and therefore allow access to the wider benefits associated with smart meters). As suggested in Section 8.4.2, one option would be a grading system where suppliers receive higher reduction points for more sophisticated display units.

11.4 Appliances

The increasing use of flat screens TVs and halogen lighting may result in 'lock in' to current technologies for many years (Green Alliance Interview). It is therefore crucial that every new appliance bought consumes as little energy as possible. Individuals need to understand what the differences in a product's performance mean, not just in terms of operational energy consumption, but also in terms of standby power, performance quality and energy costs.

Ideally, all products would be labelled in the near future using a grading system similar to the requirements outlined in the Eco-Design of Energy Using Products EU Directive. However, at the moment the regulations only encompass a limited range of white goods and air-conditioning systems. ICT and consumer electronics are not included so far, even though they contribute a significant amount to the overall energy consumption of home and it is likely that their relative contribution will increase over the next years.

The extension of mandatory energy labelling to all consumer goods will provide consumers with information on the energy consumption of all appliances. Voluntary schemes such as EST Energy Saving Recommended (ESR) labelling programme (that only endorses the top 20% of the market within a particular product group) may supplement mandatory labelling schemes and help customers to differentiate between top performing appliances.

Furthermore, siting, maintenance and operation of appliances is important. For example, freezers should not be located next to the oven and need to be defrosted regularly in order to be most efficient. End users need to be provided with

133 One issue with gas (and water) meters is the requirement for a battery as they are not mains connected.

information on appropriate use of the appliances they purchase and be persuaded to act on in.

In addition to thinking about energy consumption and stand-by power, there is also scope for limiting the "on-time" of appliances. This can be done through behavioural change such as people deciding to reduce non-essential electricity consumption e.g. by watching less TV. It can also be achieved via automation e.g. freezers could be switched off for an hour during peak demand. This would not only result in direct energy savings but could also have positive supply side impacts (see Section 10.3).

11.5 Increased uptake of DSM

The growing importance of demand side management is highlighted above. One way of encouraging DSM might be to introduce a regulated DSM programme similar to those seen in the US (in US all customers pay a system benefit charge to cover the cost of a regulated DSM programme) (National Grid Interview). A regulated DSM programme could be implemented by a number of actors: suppliers, transmission system operators, DNOs or an independent third party. Further work is required to establish the best route to achieve it.

Whilst DNOs do not have direct customer interface with consumers they a permanent link with any given property through the "Distribution Use of Service" or DUOS charge and may be better placed to recover investments in costly, long-lived measures that pay back over a long time period (Defra, 2007a).[134]

The Call for Evidence on the future Supplier Obligation suggests that to overcome the long paybacks for various energy efficient and microgeneration equipment, investment in expensive equipment could be linked to the property not the owner and paid back via an increased DUOS (Defra, 2007a)

"An investment model involving DNOs offers new ways to access the capital needed to invest in a property as well as linking liability of the debt to any future owners of the property, rather than just to the current owner. Alternatively, there may be scope for suppliers to develop other debt-transfer mechanisms to do this" (Defra, 2007a).

11.6 Changing behaviour

There is evidence that awareness campaigns and information provision needs to be tailored for different target groups. This is to capture a wide range of people and ensuring that it is not only the most that aware respond to such initiatives. The discussion on persuasion theory in Section 3.1 above highlighted that increased awareness does not necessarily lead to changes in attitude and behaviour. It highlighted the need for audience specific anchors to bind persuasion.

Greater understanding of the key factors that motivate different individuals may help to better target information campaigns and methods of communication (e.g. which agent should provide information and through what medium). Focus groups can provide insights what different people might need and how they can be

134 Currently consumers pay via their energy bills a standard charge for "Distribution Use of Service" or DuoS which covers the cost of local energy distribution.

motivated, while lessons learned from existing programmes (e.g. the CCF) can also help build the evidence base.

The issue of climate change poses specific challenges for community-based initiatives since it shares few of the characteristics[135] of typical issues for such initiatives. However, in times of rising energy prices community-based initiatives can help bring down the costs for the individual providing an additional incentive.

Programmes such as the Community Action for Energy (CAfE) of the Energy Saving Trust illustrate the scope for stimulating and supporting action to engage communities with sustainable energy and addressing the threat of climate change.

11.7 Identifying the target groups

It will be important to ensure that all groups act and that appropriate actors deliver reduction programmes together. This includes:

- **Consumers:** need for change in attitude and behaviour. This may be driven through tailored advice using research from Defra's pro-environmental behaviours segmentation model. Need to respond to policies and take advantage of free advice and cost efficient saving opportunities;

- **Suppliers:** modifications of the SO can make sure that suppliers do their bit to bring down energy consumption in the domestic sector;

- **Transmission and Distribution Network Operators**: a regulated DSM programme similar to the US could tap the potential of the DNOs and National Grid to deliver energy savings;

- **Construction industry and its supply chain**: training of skilled personnel and a clear understanding about the opportunities energy efficiency offers to the industry is key for this group; and

- **Government:** needs to set a clear long term framework for energy efficiency in the home to avoid inefficient and ineffective actions making sure all actors work together.

11.8 Barriers

There are barriers to the successful uptake of energy efficiency which need to be understood and overcome.

11.8.1 Changing behaviour

The report on Defra's framework for pro-environmental behaviours identifies a number of barriers to pro-environmental behavioural goals (Defra, 2008a):

- External, practical limits to choosing a certain behaviour (e.g. infrastructure limitations, financial constraints, working patterns, demands on time)

135 local and immediate, known beneficiaries, and clear sense of agency and potential for feedback

  - 1 in 3 felt time was a barrier. 1 in 5 said it was only worth doing environmentally friendly things if it saved you money though about half said they'd be prepared to pay more for environmentally friendly products.

- Belief that taking on new behaviours will have a negative impact on current lifestyle (particularly time) and restrict current freedoms (particularly convenience).

- Maintaining one's self-identity and negative perceptions of 'green' lifestyles and products

- About one-third felt being green is an alternative lifestyle not for the majority

- Scepticism around the climate change debate and distrust of both government and industry

  - For example, about a quarter don't believe their behaviour contributes to climate change.

- Disempowerment, as there is a disconnect between the size of the problem (Global Climate Change) and the individual's contribution (e.g. turning off lights) and a sense that individuals cannot make a difference.

  - About one third said it was not worth Britain acting, as other countries would cancel its actions out. More than half claimed if government did more, they would too.

The report stresses that motivators and barriers vary across population groups and may change over time according to life stage and other individual circumstances.

11.8.2 Inertia and a lack of interest

In its review of barriers to the uptake of renewable heat in the domestic sector, Element Energy identified two separate barrier to change, inertia and a lack of interest. This effectively reflects the fact that as individuals we simply may not want to change what we are doing, even if we are fully aware that it would benefit us e.g. by saving money. Although some individuals may never change, others may have trip points beyond which they are prepared to take action (e.g. a particular cost threshold, peer pressure, a change in lifestyle, or moving house).

In a survey undertaken as part of Defra's framework for pro-environmental behaviours (Defra, 2008a) 1 in 3 respondents felt the difficulty of changing habits was a barrier and about 1 in 5 agreed that effort was a barrier to doing more environmentally friendly things

11.8.3 Lack of end user awareness

Only 4.5% of all end users are 'energy sensitive' (i.e. have an understanding of how much being used and when, and understand the relationship with carbon emissions) (EdF Interview). There is a long way to go in terms of awareness.

Automation provides some ability to save even if customers are not that aware. For example, lighting could be switched off automatically if no movement occurs over five minutes in a room or the heating system could be switched off when the security system is switched on. However, something needs to prompt the user to install it in the first place.

Evidence gathered for Defra's framework for pro-environmental behaviours, showed that whilst many people are willing to do a bit more to limit their environmental impact, they generally have a lower level of understanding about what they can do and what will make a difference (Defra, 2008a).

Many people are unaware of the relative contributions different activities make to their total carbon footprint. Certain activities may be focused on as they require minimal lifestyle change rather than because they will have a significant impact on total GHG emissions.

In a study on public attitudes to climate change, respondents thought that out of a number of actions (e.g. flying less, improving insulation at home etc) recycling would have the greatest impact on the UK's contribution to climate change if most people in UK were prepared to do them (Defra 2008b). The survey found that the majority of people were already recycling and only a small minority were unprepared to recycle more. However nearly 25% of respondents did not want to drive less.

11.8.4 Lack of knowledge

It may be that end-users are aware of the impacts of climate change and of the fact that they impact on it, but they may still not know what they can do to reduce the impact. For instance, a common urban myth is that it is better to leave a fluorescent strip light turned on than to use the energy to start it up. Helping individuals gain a clear picture of what they can do and providing examples of where it has worked in practice can help over come this barrier.

11.8.5 Hassle

It takes time and energy to find out what the best thing to do in a home is. If individuals do not prioritise use of time for energy efficiency over other factors then it will get left to one side. Reducing the barrier to understanding and ensuring that people have a fair perception of the level of effort required can help overcome this barrier.

11.8.6 Supply-side barriers

In addition to the demand-side barriers above that may put a user off undertaking the measures described in this report, there are also barriers on the supply side. Driving the uptake of heating controls through grants and one-stop shops will lead to a limited uptake. Builders, retailers and most importantly installers need to promote the use of heating controls. Many installers are focussed on maintenance requirements and may not promote the lowest energy systems if they are more complicated than traditional systems.

Currently much of the supply chain focuses on aesthetics however in future energy will need to become a central consideration for everyone in the supply chain to drive the uptake of low energy products and design. It will be important for everyone from interior designers and the editors of home magazines right through to builders to promote low energy design.

As part of their Corporate Social Responsibility initiatives, companies should aim to work with their consumers to reduce their energy consumption and carbon emissions. This may involve training and incentivising sales staff to help customers to chose low energy products and provide advice on how to use them efficiently. In future retailers could be graded on the provision of low energy goods and advice for consumers.

11.8.7 Energy market structure

Like the rest of the EU, the UK has moved to a liberalised market, where customers frequently switch supplier and each energy activity is unbundled into different business (as opposed to vertical integration).

This presents a number of issues. Allowing customers to switch supplier presents a risk of stranded assets (a supplier may invest in a meter only for the customer to move supplier shortly afterwards). In addition, DNOs currently set the system user charge and suppliers set the energy charge. This can act as a barrier to DSM programmes since both parties need to be involved (EdF Energy Networks Interview) but it is not clear who would take a lead (also Digital Living Interview). In addition, transmission and distribution is regulated in the UK and so companies may not benefit from any cost savings beyond their price control review periods.

12. LONG TERM OUTLOOK

There is a need for a dramatic change in awareness and attitudes by 2020 in order to achieve the required reductions in energy consumption and carbon emissions in the domestic sector. In the final section of this report we consider how to maximise savings in the long-term. This helps to shape policies and interventions today and to consider factors that may not otherwise be considered.

The literature review and interviews highlighted a number of possible issues that will have a significant impact on both energy demand and supply. Given the focus of this report on behaviour, we consider how we might move to an 'engaged citizen' future where there is increased energy literacy and participation in energy systems. Of course, in practice, change will not only be driven by individuals and need not be primarily driven by them, although some level of engagement will be crucial to deliver the types of carbon target proposed. We then consider what an 'engaged citizen future' might look like in terms of:

- Homes: their appliances, micro-generation and their integration into the wide system.
- Supply: including generation, transmission and distribution.

12.1 Engaged Citizens

12.1.1 Change in attitude and increased participation

The majority of the population is now aware of climate change (Defra, 2008b) and understanding of its causes and effects is growing. Knowledge of the science for climate change is being assisted by recent increased mass media activity.

We might expect that as the population's understanding of climate change grows, the level of concern about the impacts could rise. However, the extent to which this will impact on energy use will depend on whether demonstrable progress has been made to mitigate the impacts. Failure to address the issues poses a risk to the perceived legitimacy of the actors delivering mitigation measures (be they government or other bodies). If consumers are empowered to act and given strong leadership, this concern can be more readily channelled into individual action and so these concerns lessened.

To date, policy has largely placed the responsibility for climate change mitigation in the hands of large emitters[136]. Whilst the UK has led the way in the international climate change debate, at home the public is largely insulated from the decision making process. Although CERT addresses the domestic sector's energy use, the onus is on suppliers. In a world of 'engaged citizens' this would change and individuals would have more direct responsibility for their impact, have access to the tools to enable them to respond, and be more aware of the options available to them.

12.1.2 Demand Side Participation

The electricity (and gas) energy markets do not encourage demand side participation by smaller customers. In addition, households typically face average

136 e.g. via the EU Emissions Trading System (EU ETS) and the Renewable Obligation (RO) These mechanisms, have seen some success, e.g. the RO is credited with a notable additional growth in renewable generation capacity.

costs, and there is limited transparency over how those costs are broken down (most householders are not aware of the premium they pay for supply security, for instance).

By 2020 the infra-structure for demand response could be in place. This could involve:

- Advanced meter management (AMM) meters with high resolution demand profile capture and a Teleswitch receiver[137]. This could allow flexible tariff and remote control (e.g. direct switching of appliances).

- Meters that allow customers to access raw data themselves and analyse on their PC or through internet services. By providing feedback, barriers around lack of knowledge and awareness can be overcome. This helps to create a feeling of ownership and responsibility for energy use.

- Data centres that manage and aggregate meter data (perhaps independently from suppliers) and provide information services for different actors. For instance, facilitating ESCOs who could help the domestic sector implement energy saving measures. They could also help to provide feedback and comparison across households, e.g. promoting 'competitions' and learning from others.

This would result in greater penetration of TOU tariffs and so encourage better energy management on the part of the end user. It could also promote innovation in appliance design, e.g. encouraging the development of appliances that automatically avoid peak prices.

In such a scenario, the infrastructure is in place for demand response to become a widespread, diverse and normal activity, lowering supply cost and emissions as well as mitigating price risk. In this world there would be a high degree of automation and direct switching, with consumers (or their agents) able to balance service level and price. Using accurate demand data that shows how energy use has changed over time, third parties would be in a position to offer advice and energy efficiency services in a cost effective way.

12.1.3 Feedback

One of the key features in an engaged citizen world would be the types and levels of feedback that are available to end users. Different forms of feedback would evolve to suit the diversity of consumers, with alerts to mobile phones, televisions, and audits over the internet as well as visits by local advisors. Paper bills would include advice, derived from the high resolution profile data and highlight any anomalies in recent consumption patterns.

12.1.4 Uptake of microgeneration

In this scenario, it may be more straightforward to accommodate greater penetration of microgeneration on the grid, and also into homes, as a new social norm helps to overcome reluctance to adopt new approaches. For example, solar PV and solar thermal sends a visible signal to the community, namely that 'this works, it can be done, and you could do it too'.

137 Teleswitch system would be available for suppliers and DNOs to trigger calls for demand response.

12.1.5 Benefits

The development, installation and day-to-day use of energy efficiency measures, demand response and micro-generation systems offer broad ranging social benefits of:

- Benefits of learning by doing by consumers and service providers.
- Creation of local trade and expertise (needed for transformation but currently lacking, for example external insulation is almost unheard of in the UK).
- Attitude and behaviour shaping and reinforcing through 'citizen specific' experience.

12.1.6 Overcoming financial barriers

Two fundamental components are required for such a transformation, genuine individual responsibility and strong financial drivers. Although some of the measures included in this report are no cost or low cost solutions that are already cost effective, others may need some kind of financial support. We may expect the cost effectiveness of some measures to improve over time, as mass penetration provides economies of scale and innovation provides lower cost options.

The market can be relied on to deliver some of this change itself. However, the rate at which the changes are achieved may not be fast enough for climate change targets to be met. There could be some benefits in kick-starting the uptake of some technologies or measures. There is always a reluctance to 'pick winners' or to favour a particular course of action and this concern would need to be balanced against the speed at which the engaged citizen world needs to be achieved.

12.2 Future Homes

There is considerable scope to dramatically reduce emissions from homes by 2020. Possible developments could include:

- Whole or part insulation: external insulation would become a standard for older housing stock. Internal insulation would be less favoured because of benefits of thermal mass.
- All warm air and water flows out of the building would be (measured, monitored and) managed and heat exchangers used to capture exhaust energy.
- New houses require no heating other than body heat and waste heat from appliances (see following passive homes case study).
- Control of heat in existing homes is optimised through the use of advanced controls that monitor occupancy and outside temperatures.
- Some groups of houses are encapsulated in greenhouse-type structures which proved managed thermal environment and weather protection.
- Plumbing system and appliances are optimised to avoid the use of electrical heating.

The section above on Smart Homes showed what can be achieved in terms of automation of heating, ventilation and cooling (HVAC) systems and the ability of ‘smart appliances’ to communicate to each other.

Even this world, it may still be considered unlikely that there would be a step change to a fully networked and automated house. Changes are more likely to develop in incremental steps. Any move to smart meters could be the precursor to increasingly ‘smart’ homes, and improved metering of other resources and utilities.

Space and water heating

Space heating remains the main area of focus for domestic energy policy. Much of the older housing stock would struggle to (cost effectively) achieve the insulation standards required of low or zero carbon homes. As a result, there would need to be a decarbonisation of heat, including through a move to air source and ground source heat pumps, to solar and biomass.

Depending on the relativity in the cost of fossil fuels, driven in part by the carbon price as well as international oil markets, future changes in the price of gas and a renaissance of nuclear power could cause customers to switch to electrical heating.

> *“Currently gas is used for heating & electricity for other uses but this might change. Cost mix of fuel is changing & this is being ignored. Load shifting may become important if we go for the next generation of nuclear plants* (Digital Living Interview)

This might reduce pressure on the price of gas but it may provide a challenge to both electricity supply capacity and the transmission and distribution systems.

Appliances

By 2020 we might expect there to have been significant innovation in the energy efficiency of appliances. For example:

- Competition in appliances standards could result in high efficiencies and the changes in the way an activity is undertaken altogether once theoretical limits are reached.

- Fridges are all super insulated, designed so the cold air does not escape when opened. They could avoid using motors, and instead use continuous low power semiconductor cooling systems (which do not use GHG emitting refrigerants).

- All wet appliances take their hot water from the house system which uses options such as solar thermal and heat pump technology.

- All stand-by current is removed with appliances having small batteries to drive remote control sensors.

The energy labelling of goods can be improved so that consumers understand the importance of total energy consumption and the need for correct siting, maintenance and operation. The use of appliance-level monitoring could be used to alert occupants to any poor performing appliances and suggest when a replacement might be considered.

We might also see different types of low energy homes evolving. Whilst some homes could use increasingly sophisticated technologies and networks (and may appeal to high end consumers) other homes could contain basic design features that make them very low energy.

12.2.1 Low energy homes

Low energy homes could feature passive ventilation and heating and in the extreme may not need any fossil fuel heating at all (see passive house section below). The control of heating would then become more about control of shading and blinds e.g. to control solar gain.

In such a world, there would be a need to change behaviour, as low energy homes may not achieve the same temperatures as current homes without the use of fossil fuels. People are comfortable with familiar systems and it make some time to trust new approaches. For instance, there is anecdotal evidence that some of the Passive Houses in Germany were built with boiler and radiators to reassure residents that they had a back-up (TACMA Interview).

Passive houses

Passive Houses are built to ensure a comfortable indoor climate in summer and winter, without using conventional heating systems. Passive solar design optimises the amount of energy derived directly from the sun by careful planning of buildings to collect the sun's heat. As a result a passive house only uses 10% of the energy a 'normal' home uses and only requires 15kWh/m^2 annually for space heating. In contrast, a traditional home uses around 180kWh/m^2 a year and most ordinary homes (in Scotland) only receive about 15% of their space heating from solar gain (Broxwood) (see Appendix 6).

A passive design approach can help to addressing sub-standard housing and fuel poverty. While energy use may not be reduced, quality of life and comfort can be improved. However there may be some barriers:

- **Discomfort** due to temperature extremes is a concern. Indirect or isolated approaches are more likely to be acceptable in this respect. Though they may be less efficient in theory, they may be more robust to occupancy effects.

- **Hidden costs** may outweigh fuel savings. Displacing energy use from a cheap fuel to an expensive fuel is one such hidden cost. This might arise from, for instance, an increased reliance on electric lighting resulting from reduced glazing.

- **Lack of understanding** across the supply chain: in order to follow the design intent through to completion it will be important to ensure all actors are on board. Not all agents in the building chain will appreciate the importance or the subtleties of design details.

There will be a need to educate the occupants both on the intent and the operation of their building and provide them with a 'user manual'. Care must be taken to ensure that the manual does actually reach the residents, in a form that is understandable and carries through a changing population (Alexander, D. 2002).

12.2.2 Integration of technologies

Both low energy new build and existing housing stock may move to a more fully integrated housing system that could optimise a number of interconnected systems (HVAC, lighting, appliance and microgeneration) and give increased feedback to residents. This could result in both technical and behavioural savings. For example there is considerable scope for microgeneration to be better integrated. Some ideas on a future, intelligent and integrated home are given in Figure 14 below.

Figure 14 The integrated, 'intelligent' home

"The future house is all about integration of appliances, heating/cooling systems, advanced heating controls and microgen. Need to look at how one integrated system could deliver basic needs: warmth, light, air quality, hot water etc. Also need to simplify interaction of system with user – currently many systems and controls are designed by technical people and not user-friendly. You could have central touch-screen interactive control by front door which could be linked to security system. It could operate like a car computer – tell you when something left on or poor performance. System can be calibrated to know how whole house works (both overall system (generation and loads) and user behaviour) so that it is optimised. Instead of user setting target temperature, they could just press 'I want the house warmer'. The system could also utilise data from EPC calculation and suggest long-term measures such as insulation and calculate resulting financial savings. Smart meter could connect into central system and allow for flexible tariffs and remote audits." (TACMA Interview)

"Intelligent home could make decisions on an hourly basis depending on cost of energy and carbon implications. Can remotely 'talk' to a smart home via mobile or website to control system on a time/zone or lifestyle basis" (Digital Living Interview)

12.3 Supply

12.3.1 Transmission and distribution

By 2020 transmission grid and distribution systems could have evolved (in terms of infrastructure, operation and pricing) to accommodate and promote intermittent renewables, micro-generation, micro-storage (including electric vehicles) and demand side response.

> "*Increased decentralised generation needs more robust transmission and distribution. Need to plan adequately as the assets we build now likely to be there in 50 years time*." (National Grid Interview)

Losses would be managed and reflected in pricing structures utilising both time of use tariffs and demand side response. Local energy systems would be made more resilient, with homes and neighbourhoods being able to become an 'island' in blackouts and so avoid losing critical loads.

12.3.2 Generation

A large transformation of the supply side is already underway, and under such a scenario we might expect far greater contribution from nuclear and renewable energy. Fossil fuelled power plants (presumably OCGTs) would only be used to manage imbalance at times when pumped storage or demand response was inadequate. High voltage direct current (DC) links to the continent could become more numerous, providing further diversity of supply.

> "*In the context of the Government's Renewable Energy Strategy DSM will play an important role in a future scenario wherein a high proportion of electricity generation will be from intermittent (and not particularly predictable) generation; mainly wind. May get both shortfalls and surpluses - get problems with the grid frequency. Interconnection with Europe and storage can help but also need DSM*". (EdF Energy Networks Interview)

The increased nuclear and renewable capacity increases the relative value of demand response, helping to compensate for lack of ramping and variability. Increased nuclear and wind capacity becomes possible as demand side and storage systems evolve.

> "*As intermittent generation such as wind increases will need more spinning reserve as hard to predict wind output (4 hr forecast can be as much as 50% out) and don't have enough time to get conventional back-up generation fired up. Only fossil fuelled generation that can respond quickly enough is Open Cycle Gas Turbine but mostly Closed Cycle built as more efficient (has a start up time of 4 hrs). So building more reserve capacity alone will not resolve problem – need to increase DSM. Standing reserve very expensive and carbon intensive*" (EdF Energy Networks Interview).

A large part of electricity demand is produced locally, close to demand, thus reducing transmission and distribution losses and reinforcement costs. This would allow for a reduction in the number of carbon intensive generator required as reserve capacity.

13. CONCLUSIONS

Summary

The analysis has highlighted that there is a wide range of measures to reduce electricity, gas and carbon in the domestic sector. Some of these require changes in behaviours and attitudes, while others provide technological or pricing solutions. There is some evidence that using these tools in combination will have the greatest impact.

For instance, information provision is central to ensuring existing policies deliver and that additional savings are realised. However, raising awareness and explaining to individuals how great an impact they have will only trigger the uptake of measures in a small number of circumstances[138]. In others, although information is essential to drive change, it will also be necessary to provide technological tools that further help the user change and/ or pricing signals to reinforce the incentives to change.

The most appropriate measures and the way that they can and should be combined will vary from household to household. The best approach will depend on factors including the household's: level of understanding, interest in and awareness of the issues; the energy saving actions individuals have already undertaken; the way that they use energy; and their propensity to change. As a result, different users will benefit from different packages of measures and so access to the wide range of tools is required.

Scope for government intervention

There is already a body of research highlighting that even some cost effective measures are not taken up today. One reason for this is the existence of hidden and missing costs which can mean that, in practice, measures are not viewed as cost effective by the energy user. Uptake is also reduced or delayed by a range of other barriers that can mean, for instance, that individuals are reluctant to change (inertia) or that they do not have access to sufficient support from the supply side to make the optimal choice[139].

The impact of these barriers is reflected in the quantitative analysis that we have undertaken for this project. It shows that even the implementation and delivery of firm and funded measures will result in only a relatively small reduction in energy use (and carbon emissions) between today and 2020 compared to the potential. The 'with Additional Measures' scenario (which shows an annual reduction in carbon emissions from the full implementation of existing policies scenario of 11% in 2020) would require considerable extra effort from the domestic sector if it is to be achieved. The other scenarios modelled would require an even greater step change in behaviours, attitudes and the way that energy is used by householders.

Some of this change will be delivered by the market; increased uptake will be driven through a combination of greater demand from householders themselves and as a result of the supply side identifying and promoting new opportunities. Indeed, there is already evidence of energy tariffs that reward householders for reducing their energy use and of pilot programmes to test some of the tools considered in this project. However, based on evidence in the UK to date, it is not clear that the

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138 E.g. where the individual is particularly environmentally aware.

139 By which we mean the industry that provides householders with advice, technical support and maintenance as well as those that supply energy to their home.

rate of change or the penetration levels the market achieves will be sufficient to meet the challenging UK Government carbon targets.

As a result, there is a role for government to address the following areas.

- Establish long term targets for energy use and carbon emissions, as is currently proposed in the Climate Change Bill with advice from the Climate Change Committee. This is essential if the supply side is to invest in the research and development necessary to introduce new technologies, ideas and service offerings.

- Confirm the level of effort that will be required from the domestic sector, in light of other policy goals such as fuel poverty[140]. This will provide the supply-side with some certainty that there is a long term role for delivering energy savings from this sector, and reinforce the message to the demand-side that their energy savings count.

- Take the domestic sector’s role in meeting national carbon targets into account when developing policy in other areas (e.g. transport, water and waste). For instance, the increased penetration of electric vehicles could have a considerable impact on the volume, location and timing of household electricity use.

- Provide information to persuade individuals that they have a role in combating climate change and also to ‘mobilise’ householders, to help them understand how to act and to inform them of the support available to them. This includes avoiding the penetration of mis-information or ‘urban myths’ to avoid confusion[141]. The content of such information and the way it is communicated will affect how it is absorbed and whether different individuals will act on it.

- Ensure that the supply-chain is equipped to support householders in making the optimal decision. This includes ensuring that:

    - there is sufficient supply-side capacity to install and maintain the types of technologies considered here and that households have the full picture of the help available;

    - appliance retailers are able to provide energy efficiency advice (for instance, energy labelling of products is one route to achieving consistent advice); and

    - equipment installers and maintenance providers (from heating systems to lighting) are aware of the most efficient options and how they could be used in new and existing homes[142].

- Support the delivery of energy, gas and carbon reduction measures to individuals. This can be via a range of agents (as is currently the case):

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140 By reducing household energy bills, improved energy efficiency and energy savings can address fuel poverty and will also have a positive impact on carbon emissions if the benefits are not offset by greater comfort taking.

141 For instance, recent press has implied that there is a shortage of capacity to install insulation in the UK. Enviros has not undertaken research to establish whether this is the case. One of the bodies interviewed for this project strongly rejected this view.

142 For instance, when boilers are replaced it is important to reassess the way that energy is used in the home and whether the building fabric has been improved, rather than simply reinstalling the same capacity of boiler again.

- Energy suppliers: energy suppliers enter into regular communication with householders via their energy bill. Information provided by the bill can help inform customers. Innovative tariff and service offerings can also help suppliers retain customers and potentially reduce the costs to serve. As a result, there is a role for policies like CERT, which use energy suppliers as the delivery route to achieving savings.

- Network operators: these organisations have an interest in the optimal operation of the network, in anticipating changes in the nature of demand and energy generation. The potential for charging structures and pricing schemes to provide the 'right' incentives to domestic customers in a liberalised market should be explored.

- Publicly funded bodies (e.g. Energy Saving Trust): there is some evidence that energy users have greater trust in information from organisations that they consider to be 'independent'. Such bodies consequently have a crucial role in information provision.

- Private bodies (e.g. landlords, management companies, property developers): one of the greatest challenges to delivering policy in the domestic sector is the large number of households and the relatively small energy use of each. Organisations that are responsible for groups of new and existing houses could help to facilitate increased uptake of improvements.

- Education sector (including specialist training): improved awareness of the opportunities for and benefits of better household energy management could be delivered via a range of routes. Providing training not only for those that are in full- or part-time education, but also for those undertaking specialist training, is one way to convey information to both energy users and the supply side.

◆ Increase understanding of the packages of measures that are most appropriate for different consumer groups. Monitor the measures being offered by the market to ensure that the most appropriate measures are available to different household groups.

Some of these objectives are already beginning to be addressed by existing policies (the policy review for this project highlighted that there is already a range of firm and funded measures that address some of these areas). However, there is scope for the extension of these policies to promote increased or accelerated uptake of behavioural change and other demand-side tools. Supporting programmes e.g. information campaigns and implementation support e.g. choice editing, R&D funding also have a role.

Challenges

There are a number of challenges to addressing energy use in the domestic sector, some of which are noted above. It is also important to bear in mind the fact that it can be relatively time consuming and costly to measure baseline energy consumption (particularly for a specific activity). This can make it difficult to demonstrate the savings achieved or to attribute them to a particular policy or measure. Monitoring and measuring the impact of a change in behaviour is also often not as straightforward as measuring the impact of a technology[143]. Even once

143 Since it can be difficult to separate out the change that is due to behaviour rather than other factors.

the optimal impact of a change has been ascertained, there is not always confidence that the change will last and the saving level be sustained.

As a result, it may be that a different approach to government support is required to incentivise behavioural change i.e. support that can incentivise the uptake of behavioural measures in the absence of firm quantitative evidence about their impact.

Another challenge is the fact that even once the types of initiative described above are put in place, there is no firm guarantee that they will deliver the level of savings expected. This stems in part from the difficulty around sustaining behavioural change already mentioned, and also from the fact that in some cases there may be unintended or unexpected consequences of the measures. For instance, if measures help reduce a household's fuel bill the financial saving might be used to buy new additional energy-using appliances. A common example is comfort taking, where improving the insulation of a home results in the house being maintained at a warmer temperature rather than a reduction in energy use.

Role of smart metering

Although smart metering is not essential for all of the policies in place or to encourage the uptake of some of the measures identified, it would facilitate and enhance the savings delivered by many of them. As smart meters are introduced, care should be taken to ensure that they meet the technical specifications that enable access to the full range of benefits offered by the tools.

Key features that any domestic meter would need to exhibit to deliver the maximum benefits identified above include:

- Interface facilitating remote display units that provide direct consumer feedback where the customer can readily see it, and that is presented in a way that engages the household; This same interface could be used to load historic data to PC allowing analysis by software or third-party (e.g. website)

- Advanced meter management (AMM) functionality to allow for access to all the benefits mentioned above (including flexible tariffs), allowing tariffs to appropriately reflect the evolving dynamics of the supply side.

- being flexible enough to integrate with new technology developments[144] since the roll-out process will take a number of years and associated technology will continue to evolve

- In addition, ownership of the data is crucial; in addition to information being available to the householder, some of the measures require that energy suppliers and other third parties also be allowed access to the information. We would expect that who has access to the information would be at the discretion of the energy user.

The table below illustrates how smart meters can be used in conjunction with information and awareness raising approaches to change behaviours and to incentivise reductions in energy use. As an example, it then sets out how combining a smart meter with a real time display (RTD) could affect energy use. Lastly it shows the impact that combination with additional tools (smart plugs or appliances) could have.

144 For example they should be able to communicate with appliances in a Home Area Network.

Figure 15 Illustration of potential role of smart metering when combined with other tools

	Technology	Energy and/or carbon savings achieved by
1	Smart meter	More frequent bills for electricity and gas e.g. monthly
		Historic comparisons of energy consumption on bills
		Comparisons with 'norms' or benchmarks on bills
		Advice from energy supplier or other third party based on analysis of energy use
		Increased use of pay-as-you-go tariffs
		Websites to see more detailed graphs etc of individual consumption
		Time-of-use tariffs to shift demand
2	Smart meter + RTD	Real-time information on electricity use
		Daily cumulative data on gas use
		Alerts if consumption exceeds thresholds
		Social networking sites to share info and compete
		Alerts about microgeneration output to prompt use of appliances
3	Smart meter + smart plugs or smart appliances + RTD	Detailed consumption information about individual appliances
		Appliances automatically disconnected by the supplier at peak
		Touch screen control of appliances to switch them on/ off

Note that the combinations shown in the table above are cumulative, that is the third option could in principle result in all of the outcomes listed. It is also not exhaustive; for instance, smart meters could also be used in conjunction with e.g. energy audits or heating controls to deliver savings in other ways.

As stated above, smart metering is not an essential for all of the policies in place but would be beneficial for many of them. For example, understanding how much energy is consumed by different appliances might encourage people to buy more efficient goods and one way of achieving this is through the provision of more timely and accurate information. However, the smart meter alone would not deliver these changes particularly not if its display is not easy to interpret and it is not in a prominent position in the home. Key to affecting choices and decisions is communicating the information, which could be achieved using smart metering if data is sent to through e.g. a VDU, phone or website.

APPENDICES

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2. LIST OF INTERVIEWEES

Stakeholders from the following organisations were interviewed either face-to-face or over the telephone:

- BRE
- Digital Living
- EdF
- E.On
- Green Alliance
- Green Energy Options
- National Grid
- RWE npower
- TACMA
- ERA

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3. ASSUMPTIONS USED IN SCENARIO MODELLING

Full delivery of existing policies scenario

Figures for total domestic energy consumption in the full delivery of existing policies scenario were taken from BERR (2008e). BERR provided us with a breakdown according to fuel type which we used to determine the gas and electricity consumption.

In order to break down the total energy consumption further to the level of appliances we used MTP (2008a) data. Assuming the same split of energy consumption between categories (e.g. TVs) as MTP, we then pro-rated the BERR total consumption figures using these splits to give energy consumption figures per category type.

The full delivery of existing policies scenario already includes the impacts of policies on energy savings. BERR has provided us with a figure for both gas and electricity savings which are expected from firm and funded policies. It is worth noting however that future savings from firm and funded policies are uncertain and may be revised in future.

For example, we understand that Implementing Measures under the Energy Using Products Directive legislation are significantly more stringent than previously thought and so savings from these are could well be higher than included in the BERR baseline data. Savings from future Supplier Obligations were not included in the Full Implementation of Existing Policies Scenario both because savings are uncertain and also to avoid double counting as some of the savings will come from the measures implemented in Scenarios 1, 2 and 3.

In order to estimate the remaining potential for further energy savings (after full delivery of existing policies) we have then calculated the technical potential for savings from measures which have an impact on heat consumption (based on Defra, 2007a). For electrical appliances (other than electric heaters) we have not estimated the savings induced by policies. This is because the energy consumption of electric appliances (other than electric heaters) in our other scenarios has been built bottom-up rather than top-down[145].

Table 25 Assumptions for the full delivery of existing policies scenario

Type of data	Assumption	Sources used
Total energy consumption (gas and electricity)	Applied split provided by BERR to total energy consumption figure (updated baseline with central fossil fuel prices and White Paper (WP) policies).	BERR (2008e). Updated energy and carbon emissions projections. Online: http://www.berr.gov.uk/files/file39580.pdf
Breakdown of total energy consumption by appliance type	Pro-rated BERR data on total energy consumption with MTP breakdown of appliances.	MTP (2008a). “What-If tool”, Online: http://whatif.mtprog.com
Total savings induced by	Used numbers provided by Defa.	Defra (2008c). Personal communication (September)

145 By bottom up we mean that we multiplied the number of appliances with an assumed energy consumption figure for each appliance, the consumption for each appliance thus varies from scenario to scenario.

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policies		
Technical potential for heat savings	Converted figures from Defra from carbon emissions in Mt to kWh by using the Defra conversion factors. We assumed the breakdown of savings equals the breakdown of energy consumption as presented by BERR.	Defra (2007a). The household energy Supplier Obligation from 2011 - A summary of responses to the Call for Evidence. Online: http://www.defra.gov.uk/environment/climatechange/uk/household/supplier/pdf/evidence-call.pdf

Step change scenario

We used two separate approaches to calculate the Step Change scenario.

- The first assumes no behaviour change but a switch to the most efficient appliances and deployment of insulation measures to the greatest extent possible.
- The second takes change in behaviour (such as reducing the number of appliances in the household) into account and a switch to the most efficient appliances as per the first approach.

For both the approaches we modelled the 2020 situation and assumed linear interpolation of the years 2010-2020.

Step change scenario excluding behaviour changes

First, we assumed the remaining potential for energy saving measures with an impact on the heating system (as calculated in the full delivery of existing policies scenario) will be utilised 100%. Those savings have been deducted from the full delivery of existing policies figures for both gas and electricity.

Second, we calculated the potential savings from more efficient electric appliances by using a bottom up approach. MTP (2008a) provides data on the number of units for each appliance category, which we assumed remain constant from 2010-2020. We then multiplied the number of appliances with the annual energy consumption of the most efficient model on the market. The difference between those figures and the full delivery of existing policies scenario gives the savings which can be achieved.

For electricity used for standby we assumed that it is reduced to 0 in the Step Change scenario i.e. that standby is eliminated.

Table 26 Assumptions for the Step Change scenario excluding behaviour changes

Type of data	Assumption	Sources used
Savings from measures which apply to the heating system	Converted figures from Defra from carbon emissions in Mt to kWh by using Defra conversion factors. We assumed the breakdown of savings equals the breakdown of energy consumption as presented by BERR.	Defra (2007a). The household energy Supplier Obligation from 2011 - A summary of responses to the Call for Evidence. Online: http://www.defra.gov.uk/environment/climatechange/uk/household/supplier/pdf/evidence-call.pdf

Type of data	Assumption	Sources used
Number of electrical appliances	Assumed to remain constant from 2010-2020.	MTP (2008a). “What-If tool”, Online: http://whatif.mtprog.com
Energy consumption of the most efficient model on the market	For most appliances total annual energy consumption of the most efficient appliance in each category has been provided by MTP and Öko-Institut. For some appliances we have taken MTP data on the number of uses an appliance receives per year of a unit and multiplied this figure with the energy consumption per use of the most efficient model on the market.	Öko-Institut (2008) EcoTopTen. Online: http://www.ecotopten.de/projekt_englisch.php MTP (2008a). “What-If tool”, Online: http://whatif.mtprog.com
Total energy consumption after savings	Deducted the heating system savings from gas and electricity use for heating in the full delivery of existing policies scenario and added the bottom up calculations for electric appliances. Assumed linear reduction from 2010 to 2020.	Enviros calculated
Electricity used from standby	Assumed to be eliminated by 2020.	N/A

Step change scenario including behaviour changes

For the Step Change scenario including behaviour changes we assumed a range of additional measures would be in use which further reduce energy consumption.

For the heating system we assumed that people will turn down their thermostat by 1 degree Celsius bringing down energy consumption used for household heating by a further 10%.

Furthermore, we assumed that the number of computers, monitors and TVs is reduced to one of each type of appliance per household and the number of tumble dryers is only 10% of the 2006 stock. Also, the number of drying cycles of washer dryers gets reduced by 50%. TV watching time is reduced by 50%.

More efficient cooking behaviour reduces energy consumption for cooking with hobs, ovens and kettles by 15%. We assumed no reduction for microwave oven use considering the losses as comparably low due to the timers used in microwaves. We assumed that 20% of all meals cooked on electric hobs are cooked in microwaves instead which results in 10% savings (MTP 2008b).

Table 27 Assumptions for the Step Change scenario including behaviour changes

Type of data	Assumption	Sources used
Savings from measures which apply to the heating system	As for Step Change scenario excluding behaviour changes.	As for Step Change scenario excluding behaviour changes.
Number of electric appliances	Assumed to remain constant for all cold appliances, washing machines, dishwashers, washer-dryers, hobs, ovens, microwaves, kettles, set top boxes, printers and light bulbs. Computers, monitors and TVs are assumed to equal one unit per household. The stock of tumble dryers gets reduced by 10% assuming people will dry their clothes on clothes horses.	MTP (2008a). "What-If tool", Online: http://whatif.mtprog.com
Number of times/ length appliance is used	As for Step Change scenario excluding behaviour changes except: Assumed TVs, computers and monitors each to be used 2 hours per day only. Assumed drying cycles of washer-dryers to be reduced to 50% assuming people will dry their clothes on clothes horses.	MTP (2008a). "What-If tool", Online: http://whatif.mtprog.com
Savings due to switch from electric hobs to microwaves	Assumed 20% of meals cooked on hobs are cooked with microwaves which consume only 50% of the energy per meal compared to electric hobs.	MTP (2008b). Comparing energy use in microwave ovens with traditional electric fuelled methods. Online: http://www.mtprog.com/spm/download/document/id/675
Savings from more efficient cooking behaviour	Assumed to be 15% for all cooking appliances except microwaves based on a case study with electric hobs.	Wood, G., Newborough, M. (2002) Dynamic energy-consumption indicators for domestic appliances: environment, behaviour and design. Energy and Buildings 35, 821-841
Resulting savings from turning down the thermostat	Assumed people turn down the thermostat which saves 10% of the heating energy.	Energy Saving Trust (2007) Save energy, save money, save the environment: Your guide to energy saving grants and offers. Online: http://www.energysavingtrust.org.uk/content/download/29327/95732/file/guide_to_grants.pdf
Energy consumption of the most efficient model on the market	As for Step Change scenario excluding behaviour changes.	As for Step Change scenario excluding behaviour changes.

Type of data	Assumption	Sources used
Total energy consumption after savings	As for Step Change scenario excluding behaviour changes and added additional savings from behaviour change.	
Electricity used from standby	As for Step Change scenario excluding behaviour changes.	

'Idealistic' scenario

The Idealistic scenario is based on the Step Change scenario and simply deducts those savings which are not likely to be cost effective.

We have used a cost-effectiveness condition of less than 5 years payback for a measure, which is in line with the assumptions of an inter-government-departmental analysts group and the Energy Saving Trust (2006).

For most measures the Energy Saving Trust (2006, 2008) provides payback periods, with the exception of figures for ICT and consumer electronics. Our own market research shows that most electronic appliances which are considered efficient, but not necessarily the 'state of the art most efficient' on the market, are not more expensive or cheaper than average products. Therefore we assumed that it will always be cost effective to use an efficient electronic appliance. We have used the MTP database for obtaining consumption values of efficient models- these are somewhat less efficient than those values used for the Step change.

Energy savings due to behaviour changes are always considered as cost effective because a change of behaviour does not cost money and the savings will save money. For the same reason switching off standby is considered as cost effective.

Assuming by 2020 all cost effective measures are fully implemented, the years 2010-2020 are calculated based on linear interpolation from full delivery of existing policies in 2010 to the Idealistic figures for 2020.

Table 28 Assumptions for the Idealistic scenario

Type of data	Assumption	Sources used
Definition of cost effectiveness	Assumed all measures to be cost effective with pay back periods equal to or below 5 years.	Inter-departmental analysts group (IAG) (2008). Long-term reductions in greenhouse gas emissions in the UK. Online: http://www.berr.gov.uk/files/file38187.pdf
Cooking measures	Assumed cost effective with reductions, as in the Step change.	

Type of data	Assumption	Sources used
Payback periods for insulation measures, heating and hot water, lighting and white goods	Payback periods for white goods, heating and hot water measures and lighting all below 5 years. All insulation measures have payback periods <5 years with the exception of cavity wall insulation (payback 5-6 years if done in flats) and solid wall insulation (payback periods only <5 years in detached houses and bungalows).	Energy Saving Trust (2006). Domestic Energy Primer – an introduction to energy efficiency in homes. Online: http://www.energysavingtrust.org.uk/uploads/documents/housingbuildings/CE101.GPG171%20-%20Domestic%20energy%20efficiency%20primer.pdf Energy Saving Trust (2008) Tanks and pipes insulation. Online: http://www.energysavingtrust.org.uk/home_improvements/home_insulation_glazing/tanks_and_pipes_insulation/
Payback periods for ICT, consumer electronics and white goods.	Computers: Thin clients are cheaper than normal computers/ laptops (example: Smart Client from Cranberry: £349) TVs: EST recommended TVs involve no extra costs (example: Sharp LC-20AD5E: £329) Set top boxes: Prices for EST recommended models are similar to other models, no extra costs (example: Sagem ITD 58G DVB-T: £19.95). Printers: Prices of EST recommended models are similar to other models, no extra costs (example: Epson Stylus D92: £27.50). Monitor: Prices are similar to other models, no extra costs (example: BenQ G700: £104.35).	Enviros market research
Savings from switching off standby	Assumed to be always cost effective.	
Savings due to behaviour changes	Assumed to be always cost effective.	

Additional Measures scenario

In the Additional Measures scenario we further constrain the energy savings which can be achieved. Although some savings are cost effective, people might not always act in line with a cost-benefit rationale.

The Additional Measures scenario is based on the Idealistic scenario. We assumed that all cost effective insulation and heating control measures are only implemented by the most environmentally conscious group of the population as defined by Defra (2007b). We assumed a linear increase of energy savings from the full delivery of existing policies 2010 figure to the Additional Measures scenario in 2020.

For all goods which are labelled via the European Union (EU) energy label (most white goods and light bulbs), we assumed replacement of the current stock with the most energy efficient model on the market. Where such a label is not available, we assume no uptake of energy efficient products. Although it is cost effective for some products (e.g. light bulbs) to be replaced with a more efficient appliance before the end of their life, realistically people are not going to replace appliances before a product reaches the end of its life. Therefore we calculated current replacement rates and constrained the replacement of old appliances with new ones accordingly.

For standby we assumed that the EU proposals for the reduction of energy consumption from standby will be implemented leading to a reduction of 73% by 2020. The remaining 27% is further reduced by the most environmentally conscious group of the population as defined by Defra (2007b) which switches off standby.

Table 29 Assumptions for the Additional Measures scenario

Type of data	Assumption	Sources used
Definition of most environmentally conscious group of population	Assumed to be 18% (positive greens).	Defra (2007b) Survey of Public Attitudes and Behaviours toward the Environment. Online: http://www.defra.gov.uk/environment/statistics/pubatt/download/pubattsum2007.pdf
Replacement rates	Calculated by using data on stock, sales and growth of appliances. Assumed replacement of old appliances with energy efficient ones according to replacement rate.	MTP (2008a). "What-If tool", Online: http://whatif.mtprog.com
Savings from switching of standby	Assumed that standby consumption is reduced by 73% by 2020 due to EU regulation. Assumed that most environmentally conscious group switches of the remaining standby.	Europa (2008). Press release. Member States endorse Commission proposal to reduce standby electricity consumption. Online: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/1117&

4. OUTPUTS FROM SCENARIO MODELLING

Business as usual with firm and funded policies

For the business as usual figures on total energy consumption and the split of electricity to gas consumption are taken from BERR and are set out in the table below.

Table 30 Total energy consumptions and % split to gas and electricity under full delivery of existing policies

	2010	2015	2020
Total (TWh)	480	444	392
Electricity (% of total)	68%	67%	64%
Gas (% of total)	24%	26%	29%

Source: BERR, 2007a

The total figures provided by BERR for the full delivery of existing policies scenario include the effect of firm and funded policies that are already in place. Projections of energy reductions from these policies provided by BERR[146] and are shown in Table 31.

Table 31 Policies and associated gas and electricity reductions (TWh) included in the full delivery of existing policies scenario

Measure	Fuel	2010	2015	2020
Energy Efficiency Commitment first phase (EEC1) (2002-2005)	Gas	0.41	0.41	0.41
	Electricity	1.54	1.54	1.54
EEC2 (2006-2008)	Gas	5.41	5.41	5.41
	Electricity	1.38	1.38	1.38
EEC3 (CERT) (2008-2011)[147]	Gas	8.91	9.80	9.80
	Electricity	3.67	4.00	4.00
Home Energy Efficiency Scheme (HEES) / Warm Front 1 (WF1)	Gas	0.43	0.43	0.43
	Electricity	0.22	0.22	0.22
WF2	Gas	-2.01	-2.30	-2.30
	Electricity	1.70	1.95	1.95
Building Regulations 2002	Gas	9.71	10.59	10.59
	Electricity	0.39	0.43	0.43
Building Regulations 2005	Gas	13.02	14.01	14.01
	Electricity	0.12	0.14	0.14
Others	Gas	-0.42	-0.25	-0.25
	Electricity	1.60	1.71	1.71

146 Revisions to CERT, EEC1 and EEC2 provided by Defra.
147 Excluding 20% extension.

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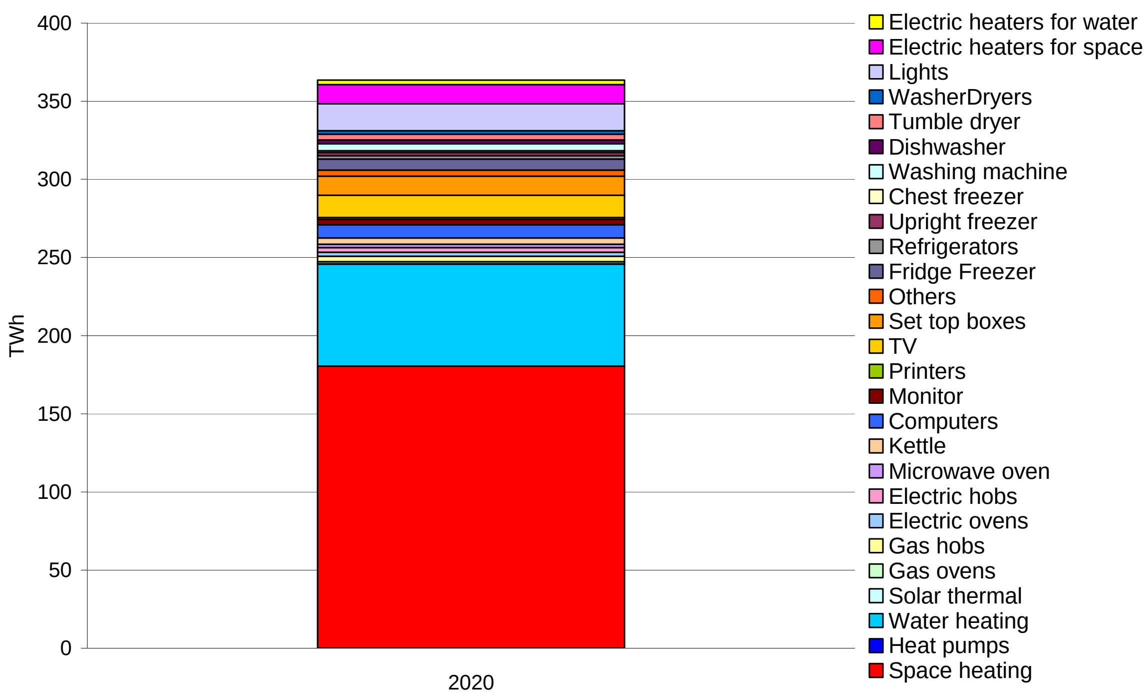
Total	Gas	26.64	28.39	28.39
	Electricity	7.86	8.27	8.27

Source: Defra, September 2008c

In addition there will be savings from the 20% expansion of CERT recently announced and from future Supplier Obligations. These were not factored into the existing policies baseline to avoid double counting (as many of the measures incorporated in the scenarios may be delivered through the CERT expansion and future SO).

Figure 16 illustrates the breakdown of total energy consumption by end-use categories that has been assumed for the business as usual scenario in 2020. This is based on MTP data.

Figure 16 Energy demand (TWh) by end use categories under the full delivery of existing policies scenario.



Energy consumption across the majority of the end use categories is projected to decline, driven primarily by improved efficiency. However, in some electric categories (e.g. set-top boxes, and the 'others' category which includes video recorders and power chargers) energy consumption is projected to increase because the uptake of new appliances is projected to far outstrip savings from improved efficiency.

Step change scenario

The table below provides a breakdown of the projected reductions in gas and electricity consumption between 2010 and 2020 for each end-use category under Scenario 3 (the Step change). The reduction in demand for both gas and electricity increases over time. The annual reduction in gas (125TWh) by 2020 is greater than that in electricity (73TWh).

- The installation of solar thermal has the largest impact on gas savings. Other high impact measures are the take-up of heating controls and behavioural changes to reduce space heating.

- The replacement of light bulbs, TVs and set-top boxes with efficient models has the largest impact on electricity savings.

Table 32 Projected energy reductions (TWh/year) in 2010, 2015 and 2020 by end-use categories under scenario 3 (Step change)

Fuel type	End use	Measure	2010	2013	2015	2020
Gas	Space heating	Boiler and pipe insulation	0.00	2.72	4.53	9.16
		Cavity wall insulation	0.18	4.46	7.31	14.63
		Solid wall insulation (internal)	0.21	5.18	8.50	17.00
		Solid wall insulation (external)	0.00	0.53	0.89	1.80
		Loft insulation (original <=100mm)	0.00	2.77	4.62	9.36
		Loft insulation (original >100mm)	0.00	0.87	1.45	2.93
		Behaviour response to better information	1.14	4.57	6.85	12.56
		Advanced heating control	1.94	7.77	11.65	21.36
		Heat pumps	0.01	0.11	0.47	2.84
	Water heating	Solar thermal	0.00	0.00	0.12	31.72
	Cooking	Ovens	0.32	0.55	0.73	1.10
		Hobs	0.48	0.61	0.70	0.61
Total gas	**All**	**All**	**4.28**	**30.14**	**47.83**	**125.09**
Electricity	Cooking	Ovens	0.00	0.11	0.17	0.20
		Hobs	0.09	0.52	0.80	1.37
		Microwaves	0.00	0.07	0.11	0.15
		Kettle	0.06	0.47	0.73	1.26
	ICT	Computers	0.95	2.84	4.08	8.13
		Monitor	0.51	1.49	2.13	3.14
		Printers	0.00	0.25	0.42	1.00
	Consumer electronics	TV	2.30	6.71	9.59	13.41
		Set top boxes	0.86	3.69	5.89	12.12
		Others	0.21	0.94	1.42	3.12

Fuel type	End use	Measure	2010	2013	2015	2020
	Cold appliances	Fridge Freezer	0.21	1.34	2.08	3.98
		Refrigerators	0.03	0.28	0.44	0.88
		Upright freezer	0.06	0.39	0.60	1.15
		Chest freezer	0.01	0.13	0.21	0.52
	Wet application	Washing machine	0.18	1.01	1.54	2.80
		Dishwasher	0.00	0.17	0.28	0.55
		Tumble dryer	0.30	1.33	2.00	3.43
		Washer Dryers	0.08	0.43	0.65	1.13
	Lighting	Lighting bulbs	0.94	4.72	7.18	12.84
	Heat pumps	Heat pumps	0.00	-0.03	-0.12	-0.75
	Solar thermal	Electric heaters for space	0.07	0.08	0.09	0.09
		Electric heaters for water	0.32	1.29	3.18	2.92
Total electricity	**All**	**All**	**7.18**	**28.22**	**43.47**	**73.40**
Total			**11**	**58**	**91**	**198**

Idealistic scenario

The table below provides a breakdown of the projected reductions in gas and electricity consumption between 2010 and 2020 for each end-use category under Scenario 2 (the Idealistic scenario). The reductions in demand for both gas and electricity increase over time.

However, in contrast to Scenario 3, in Scenario 2 projected reductions in electricity (59TWh) by 2020 are greater than the reductions in gas (56TWh).

- The take up of heating controls, cavity wall and loft insulation have the largest impact on gas reductions
- Replacement of light bulbs and set-top boxes by efficient models and the uptake of low standby electricity consumption appliances have the largest impact on electricity reduction.

Table 33 Projected energy reductions (TWh/year) in 2010, 2015 and 2020 by end-use categories under scenario 2 (Idealistic)

Fuel type	End use	Measure	2010	2013	2015	2020
Gas	Space heating	Boiler and pipe insulation	0.00	2.72	4.53	9.16
		Cavity wall insulation	0.14	3.61	5.92	11.85
		Solid wall insulation (internal)	0.00	0.00	0.00	0.00

Fuel type	End use	Measure	2010	2013	2015	2020
		Solid wall insulation (external)	0.00	0.00	0.00	0.00
		Loft insulation (original <=100mm)	0.00	2.77	4.62	9.36
		Loft insulation (original >100mm)	0.00	0.87	1.45	2.93
		Behaviour response to better information	3.80	3.58	3.44	2.92
		Heating control	2.13	8.04	11.59	18.05
		Heat pumps	0.00	0.00	0.00	0.00
	Water heating	Solar thermal	0.00	0.00	0.00	0.00
	Cooking	Ovens	0.32	0.55	0.73	1.10
		Hobs	0.48	0.61	0.70	0.61
Total gas	**All**	**All**	**6.87**	**22.76**	**32.99**	**56.00**
Electricity	Cooking	Ovens	0.00	0.11	0.17	0.20
		Hobs	0.09	0.52	0.80	1.37
		Microwaves	0.00	0.07	0.11	0.15
		Kettle	0.06	0.47	0.73	1.26
	ICT	Computers	1.10	4.14	4.99	5.02
		Monitor	0.33	1.37	1.63	1.47
		Printers	0.11	0.40	0.40	0.46
	Consumer electronics	TV	0.83	3.39	5.12	5.84
		Set top boxes	0.61	3.36	6.20	9.88
		Others	0.26	1.13	1.80	3.13
	Cold appliances	Fridge Freezer	0.08	0.32	0.47	0.79
		Refrigerators	0.04	0.16	0.24	0.41
		Upright freezer	0.04	0.16	0.24	0.39
		Chest freezer	0.02	0.07	0.10	0.16
	Wet application	Washing machine	0.02	0.07	0.10	0.18
		Dishwasher	0.02	0.07	0.10	0.18
		Tumble dryer	0.05	0.19	0.28	0.47
		Washer Dryers	0.01	0.02	0.03	0.06
	Lighting	Lighting bulbs	0.94	4.72	7.18	12.84
	Heat pumps	Heat pumps	0.00	0.00	0.00	0.00
	Solar thermal	Electric heaters for space	0.00	0.00	0.00	0.00

Fuel type	End use	Measure	2010	2013	2015	2020
		Electric heaters for water	0.00	0.00	0.00	0.00
	Standby electricity	Reduction in standby through efficient appliances	0.93	3.75	5.65	10.69
		Reduce unnecessary standby	0.36	1.46	2.20	3.96
Total electricity	**All**	**All**	**5.92**	**25.98**	**38.54**	**58.88**
Total			**13**	**49**	**72**	**115**

'Realistic' scenario

The table below provides a breakdown of the projected reductions in gas and electricity consumption between 2010 and 2020 for each end-use category under Scenario 1 (the Additional Measures scenario). As in the other scenarios there is a reduction in demand for both gas and electricity which increases over time. The 2020 reductions in electricity (22TWh) are far greater than those projected in gas (9TWh).

- The take up of new heating controls, albeit by only a small section of the population, has the largest effect on gas reductions.
- Replacement of light bulbs has the largest effect on electricity reduction.

Table 34 Projected energy reductions (TWh/year) in 2010, 2015 and 2020 by end-use categories under scenario 1 (Additional Measures)

Fuel type	End use	Measure	2010	2013	2015	2020
Gas	Space heating	Boiler and pipe insulation	0.00	0.49	0.81	1.65
		Cavity wall insulation	0.03	0.65	1.07	2.13
		Solid wall insulation (internal)	0.00	0.00	0.00	0.00
		Solid wall insulation (external)	0.00	0.00	0.00	0.00
		Loft insulation (original <=100mm)	0.00	0.50	0.83	1.69
		Loft insulation (original >100mm)	0.00	0.16	0.26	0.53
		Behavior response to better information	0.00	0.00	0.00	0.00
		Heating control	0.38	1.45	2.09	3.25
		Heat pumps	0.00	0.00	0.00	0.00
	Water heating	Solar thermal	0.00	0.00	0.00	0.00
	Cooking	Ovens	0.00	0.00	0.00	0.00
		Hobs	0.00	0.00	0.00	0.00
Total gas	**All**	**All**	**0.41**	**3.24**	**5.06**	**9.24**

Fuel type	End use	Measure	2010	2013	2015	2020
Electricity	Cooking	Hobs	0.00	0.00	0.00	0.00
		Microwaves	0.00	0.00	0.00	0.00
		Kettle	0.00	0.00	0.00	0.00
	ICT	Computers	0.00	0.00	0.00	0.00
		Monitor	0.00	0.00	0.00	0.00
		Printers	0.00	0.00	0.00	0.00
	Consumer electronics	TV	0.00	0.00	0.00	0.00
		Set top boxes	0.00	0.00	0.00	0.00
		Others	0.00	0.00	0.00	0.00
	Cold appliances	Fridge Freezer	0.08	0.29	0.42	0.71
		Refrigerators	0.04	0.15	0.21	0.37
		Upright freezer	0.04	0.15	0.21	0.35
		Chest freezer	0.02	0.06	0.09	0.14
	Wet application	Washing machine	0.01	0.06	0.09	0.16
		Dishwasher	0.02	0.06	0.09	0.16
		Tumble dryer	0.04	0.17	0.25	0.43
		WasherDryers	0.01	0.02	0.03	0.05
	Lighting	Lighting bulbs	2.61	8.84	8.88	8.71
	Heat pumps	Heat pumps	0.00	0.00	0.00	0.00
	Solar thermal	Electric heaters for space	0.00	0.00	0.00	0.00
		Electric heaters for water	0.00	0.00	0.00	0.00
	Standby electricity	Standby of electric appliances	0.93	3.75	5.65	10.14
		Standby of electric appliances	0.07	0.26	0.40	0.71
Total electricity	**All**	**All**	**3.85**	**13.82**	**16.33**	**21.94**
Total			**4**	**17**	**21**	**31**

5. SUPPLY SIDE QUANTIFICATION ASSUMPTIONS

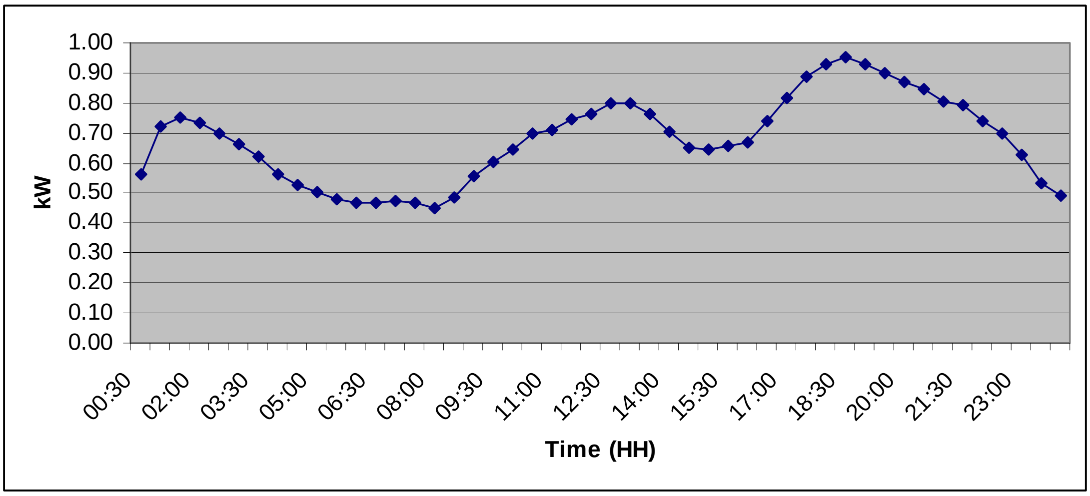
In order to estimate the impact of demand side measures on peak demand we took the follow approach.

- A half-hourly load profile for domestic customers on a standard or Economy 7 tariff was used as the starting point. The day with highest half-hourly peak demand was chosen[148].

- An estimate was made about the proportion of households that are on an Economy 7 tariff and a standard tariff (assumed to be 21%[149]).

- Using this estimate and aggregate domestic sector half-hourly electricity use load profile was constructed, illustrated in the chart below.

Table 35 Illustrative half-hourly electricity load profile for domestic customers



Note: based on a Sunday. The peak in demand between 12:00 and 13:30 is not replicated during the week or on Saturdays.

- Based on the information used for the Scenario modelling, we have estimated which energy uses contribute to the evening peak and the demand side reduction that could be achieved through more energy efficient appliances at that time, shown in the table below.

148 From the load profiles developed by the Profile Administrator (PrA) which are applied to the Balancing and Settlement Code. These profiles depict typical daily energy demand patterns throughout the year for an average customer for eight profile classes. Profile Classes 1 (domestic unrestricted) and 2 (domestic restricted) were used.

149 Based on ELEXON extracted from a snapshot (from 10/02/08) of the Supplier Purchase Matrices (SPMs) which showed the 79% of customers were on a Profile Class 1 tariff.

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Table 36 Energy savings from appliances

Type of appliance	Energy demand (kW)		
	Using standard appliances	Using energy efficient devices	Using energy efficient devices and load shifting (see below)
Cooking	0.21	0.13	0.13
ICT (e.g. computers)	0.02	0.01	0.01
Consumer Electronics (e.g. Televisions)	0.17	0.11	0.10
Cold applications (e.g. fridge freezers)	0.03	0.01	0.01
Wet applications (e.g. washing machines)	0.12	0.09	0.02
Lighting	0.39	0.07	0.06
Total	**0.94**	**0.42**	**0.33**

- The potential for moving energy demand away from the peak period was then considered and applied to the energy efficient devices (shown in the table above). We based the estimate on the assumptions shown in the table below.

Table 37 Potential to load shift different types of appliance using automation and TOU tariffs

Type of appliance/ system	Potential to automate	Potential saving (%)	Potential to shift demand using TOU tariffs	Potential saving (%)
Cooking	Very little – may be able to remotely turn on oven	0	Very little as cooking essential use	0
ICT	No savings possible	0	Some – for example some internet users may be prepared to delay downloading a film	10
Consumer electronics	No savings possible	0	Some – for example some internet users may be prepared to delay downloading a film	10
Cold appliances	Medium potential – could switch off appliances for up to 1 hour during peak. However health and safety issues would need to be addressed	20	Very low as people unlikely to actively control appliances they aren't used to switching on or off. Manufacturer may not want to include in appliances.	0

Type of appliance/ system	Potential to automate	Potential saving (%)	Potential to shift demand using TOU tariffs	Potential saving (%)
Wet application	Some potential e.g. put washing and powder in and shut door. Machine only turned on remotely during night. Although most people would want to have ability to over-ride.	20	Good potential – some users may be prepared to wait to turn on wet appliances until peak period ended.	60
Lighting	Limited to light sensors which reduced total consumption not just peak consumption.	0	Low – but increased awareness may lead to improved behaviour	5

6. PASSIVE HOMES

A move to passive homes could significantly reduce energy consumption from new homes. Table 38 compares the typical features of a passive home with new build common practise in the UK.

Table 38 Comparison of PassivHaus Standards with common practise in new build (PassivHaus)

Feature	PassivHaus Standard	UK new build common standard
Compact form and good insulation:	All components of the exterior shell of a PassivHaus are insulated to achieve a U-Value that does not exceed 0.15 W/m2/K	Limiting U-values of approximately 0.25-0.35 W/m2/K
Southern orientation and shade considerations:	Passive use of solar energy is a significant factor in PassivHaus design.	Some consideration is given with regard to north/south orientation, but the improved energy savings resulting from passive site design are often overlooked.
Energy-efficient window glazing and frames:	Windows (glazing and frames, combined) should have U-Values not exceeding 0.80 W/m²/K, with solar heat-gain coefficients around 50%[150].	1.8-2.2 W/m2K typical
Building envelope air-tightness:	Air leakage through unsealed joints must be less than 0.6 times the house volume per hour (this is the equivalent of an air permeability value of less than 1 m3/hr/m2 @ 50 Pa).	Design air permeability of 7 to 10 m2/hr/m3@ 50 Pa. This is approximately a factor of 10 poorer than the PassivHaus standard. Research has also shown that air permeability values for completed dwellings frequently exceed these design limits.
Passive preheating of fresh air:	Fresh air may be brought into the house through underground ducts that exchange heat with the soil. This preheats fresh air to a temperature above 5°C (41°F), even on cold winter days.	The majority of new-builds do not achieve good enough air permeability values to warrant the incorporation of a whole house ventilation system - thus trickle vents, extract fans, or passive stack ventilation is commonly used.
Highly efficient heat recovery from exhaust air using an air-to-air heat exchanger:	Most of the perceptible heat in the exhaust air is transferred to the incoming fresh air (heat recovery rate over 80%).	

150 The Solar Heat Gain Co-efficient (SHGC) is provided as a guide, it can be adjusted for glazing on different facades. This can help either reduce heat loss on sheltered sides/ north facing glazing, or alternatively help to reduce the likelihood of overheating when specified in conjunction with other features/strategies (please note that the SHGC of a window usually decreases as the U-value improves).

Feature	PassivHaus Standard	UK new build common standard
Energy-saving household appliances:	Low energy refrigerators, stoves, freezers, lamps, washers, dryers, etc. are indispensable in a PassivHaus.	Dedicated low-energy lights are provided in a number of rooms in a new dwelling - if appliances are supplied they will be generally C-rated or perhaps 'Energy Saving Recommended' in some instances (as these are widely available).
Total energy demand for space heating and cooling	Less than 15 kWh/m2/yr	Typically 55 kWh/m2/yr

Construction costs of passive houses are 8%-10% higher than those of conventional houses because of the high cost of individual components of construction (Broxwood). However, passive houses deliver up to 40% savings in operational costs of the house. Savings can actually pay back the cost in two years (University of Strathclyde, 2002).

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