Heat in Homes: customer choice on fuel and technologies

Study for Scotia Gas Networks

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Preface

This paper examines the current direction of UK energy policy to consider its implications for consumers with respect to the fuels and technologies used to meet household heat requirements.

The UK has set an ambitious carbon reduction target to the 2050s, whilst also working towards an EU target to increase the share of renewable energy by 15% by 2020. These have become key drivers in shaping energy policy, with implications for both the supply and demand sides of the energy system across all sectors of the UK economy. High-level modelling and scenarios increasingly suggest that meeting these targets will require increased energy efficiency, decarbonising generation and expanding the use of electricity into heat and transport, and a more electric-centric future now appears to be significantly shaping the direction of policy.

Towards 2020 the focus is on improving energy efficiency, reducing the demand for both gas and electricity helping to increasing affordability, and in the case of gas, also helping to reduce emissions. Policy is also starting to encourage the uptake of low carbon heat. Between 2020 and 2030 the demand for gas is expected to continue to decline, whilst the demand for electricity is expected to start significantly increasing, in part reflecting the uptake of electric heat, which within the domestic sector appears to be mainly in new build and off-gas households. Post-2030, the projections suggest that renewable heat will also significantly penetrate the on-gas housing market.

The possible changes towards a more electric future have significant long-term implications for the way in which gas may be used within the domestic sector. Although total domestic demand for gas appears to have peaked, its use still dominates final energy consumption. For heat, including space heating, hot water and cooking, gas accounts for around 84% of total household energy consumption, meeting around 83% of space heating demand, 78% of hot water demand (mainly through wet-based central heating systems) and also meeting 52% of cooking demand, with a preference towards the use of gas for hobs and electricity for ovens.

The current dominance of gas in meeting heating requirements reflects the fact that around 84% of homes are on the gas network, as well as its current cost advantages compared to most other fuels in terms of both upfront capital and running costs. It is also seen as reliable and familiar, and is supported by a mature installation and maintenance market. Although an under-researched area, the evidence suggests that consumers are generally highly satisfied with the current way that space heating and hot water are provided, i.e. mainly through gas fired central heating. However, actual choice can be limited by a range of factors, including access to the gas network, type of tenure and building characteristics such as dwelling age and type, and household type. Choice can also be influenced by attitudes and behaviour, with research suggesting that people tend to discount future benefits, use defaults and be influenced by social norms. This can be linked to consumers failing to install insulation measures, even if they are cost effective, and evidence to suggest that they are only willing to make changes that require low levels of disruption or lifestyle change. Combined, these issues create challenges (1) for reducing household energy demand and (2) for encouraging the uptake of renewable heat.

Most modelling sees a role for heat pumps, biomass and solar thermal within the domestic sector, but these all face a range of barriers to uptake in comparison to conventional heating sources.

In addition to cost, these include concerns over reliability, ease of use, compatibility with current systems and lifestyles, and consumer confidence and awareness, as well as wider supply-chain constraints. There is also a ‘default to gas’ in on-gas areas. This in part reflects the high levels of satisfaction with the way that heat is currently provided, as well as wider evidence that suggests people attach a low priority to considering changes, unless there are specific problems. Furthermore there is a tendency towards repairing existing boilers when possible and, when not, replacing them with a broadly like-for-like condensing model, often as a distress purchase. A potential way to address this inertia is to work with natural intervention points, which can include periods of renovation, repair or maintenance in homes under existing ownership, or during the sale of homes; and policy developments such as the Green Deal, ECO, RHI and FiTs may help to increase the opportunities that are available at these points.

There appears to be considerable potential for rolling out renewable heat in off-gas homes, subject to their effective insulation, and even more so in the projected number of new builds up to 2030. What is less clear, given the points above, is what will prompt on-gas consumers to switch away from gas as their technology and fuel for heat, as there is a significant gap between where consumers are now and where the modelling and policy suggests they will be post-2030, unless the prevailing economics of household heat change very significantly or unless regulation starts to encourage consumers in that direction. In addition, the prominence that is being given to driving electrification of heat perhaps underplays the near-term and significant opportunities to maximise the efficiency of gas within existing homes, both pre-2020 and beyond. Household gas use currently accounts for around 14% of all UK GHG emissions, so there is considerable potential for saving carbon (whilst reducing fuel bills and improving levels of thermal comfort) and more policy attention should be given to improving efficiency in on-gas households now, as part of the whole development of the UK’s energy policy. This could include upstream measures to reduce losses and make more use of biogas, which would also help to avoid the range of barriers associated with alternative forms of renewable heat; as well as the very considerable downstream scope with respect to replacing inefficient boilers, installing better controls and supporting the development of newer technologies.

Until the picture for technology and fuel choice for household heat is better quantified and understood from a consumer perspective, there is a risk that more expensive pathways to decarbonisation are incentivised at the expense of alternatives which may be both cost-effective and attractive from a customer viewpoint. Near- and medium-term investment decisions, both by actors in the gas sector and by individual households, need to be underpinned by a more strategic view of the role anticipated for gas in the UK energy system in the future.

Based on these findings, more work is needed with consumers to engage them with possible future heat developments, as well as to better understand their underlying preferences for the provision of heat, particularly in on-gas households. There should also be further analysis in relation to what these preferences could mean for the modelling for a more electric-centric future, as well as further work on the likely cost and emissions savings, based on a more efficient role for gas within the domestic sector.

Executive Summary

This research analyses and considers a number of key issues with regard to the way that heat is currently used within the domestic sector, largely for space heating and hot water, and to a lesser extent for cooking, based on a set of research questions agreed with Scotia Gas Networks:

- What are the main fuels and appliances for heating, hot-water and cooking in homes?
- What are the main determinants in making these choices? What characteristics of (1) gas (2) oil and (3) electric (on-peak & off-peak) heating do customers particularly like or dislike. What are the reasons?
- Do consumers have a preference for the use of gas cooking compared to other cooking technologies and, if so, what are the reasons?
- Do consumers seek any particular characteristics or have any preferences when thinking about how their heating technologies are going to change in the future?
- Is there any emerging evidence describing levels of consumer satisfaction with renewable heating technologies such as heat pumps, solar thermal, biomass boilers?

The transition to low carbon

In order to reduce the threat of climate change the UK has set an ambitious 2050 carbon reduction target that reflects its global role for emission reductions. This, along with the target for increasing the share of renewable energy by 15% by 2020, has become a key driver in shaping the direction of energy policy, along with wider goals to increase energy security whilst trying to ensure affordability. In order to understand the implications of meeting these targets, an increasing number of models and scenarios have been developed to explore the possible routes to achieve this, mainly considering what will be technically feasible.

A common feature of these top-down models is that they anticipate that the most effective way to reach the targets will be based on increasing energy efficiency, decarbonising power generation and expanding the use of electricity into heat and transport, essentially a much more electric-centred future. Policy developments have increasingly sought to enable this to happen both pre- and post-2020 and a vision of a more electric future now appears to be significantly shaping policy.

There are also some very effective policy developments that are supportive of gas and its role within the energy system, including those that aim to improve the energy efficiency within homes, the CCS demonstrations and biomethane injection into the grid. However, at the same time many of the new policies for households and communities are clearly more orientated towards the promotion of electricity, including the RHI, FiTs, Smart Grids and Zero Carbon Homes.

Pre-2020, much of the policy focus very sensibly seeks to improve energy efficiency, reducing the demand for both gas and electricity (through a combination of insulation measures, tougher product standards and increased customer awareness) to increase affordability and, in the case of gas, to reduce emissions, whilst also starting to encourage the uptake of renewables for heat and for low-carbon electricity in all sectors of the economy, including the domestic sector.

As we move beyond 2020 towards the 2030s, the policy ‘default’ is for household gas demand to continue to fall, whilst the demand for electricity is expected to significantly increase – including being incentivised to do so, subject to electricity decarbonisation and overall system efficiency. During this period it appears that the uptake of renewable heat will predominately focus on new build and off-gas households. Post-2030, significant uptake is also anticipated in on-gas housing.

The drive towards a low carbon and more electric future has significant implications for on-gas households post-2030, particularly in respect of the way that heat is provided now and expectations on heat provision into the future – yet very limited work has taken place with consumers around what is being proposed. A range of complex interactions drives household energy use, these being structural (location, tenure type, household size, etc), economic (disposable household income and proportion of expenditure on fuel costs etc), social (status, meaning, identity, etc). Household use is also shaped by everyday consumption practices and habit. Given the very fundamental changes that are being proposed, not only in terms of large scale system change but also expectations on the technologies and patterns of demand within households, understanding these interactions and the public perceptions and preferences towards heat will be a key element of a successful low carbon future (Whitmarsh et al 2011).

Fuel and technology use in the domestic sector

The long-term trends in household energy consumption show that consumption of different fuels and end uses has changed over time. There was an upward trend in total consumption until 2004, when gas use appears to have peaked, most likely as a result of increases to thermal and boiler efficiency. Since then demand for household gas has been reducing, whilst demand for electricity has continued to increase. The split in household fuel use shows that final energy consumption for 2008 was provided by: gas 68%; electricity 24%; oil 7%; and solid fuels 1%.

In respect of household heat use, consumption is influenced by a wide range of structural factors that can also influence the type of technologies and fuels that are used, and in the case of space heating there are also seasonal and yearly peaks influenced by external temperature. This results in changes in heat consumption from year to year. However, for 2008, 84% of total household energy consumption was from the use of heat, in particular space and water heating. In comparing fuels with final end uses for households, gas provided:

- 83% of space heating demand;
- 78% of hot water demand;
- 52% of cooking[1] demand.

The dominance of gas is in part explained by the high penetration of the gas network, with around 84% of UK homes having access to gas, but it also reflects the relative cost effectiveness of this fuel compared to on-peak electricity, oil and solid fuels for heating, as well as the infrastructure, manufacturing and installation/maintenance base that has developed to support the use of gas.

In respect to the technologies, most space heating needs are met through central heating systems, which are now present in over 92% of homes. The majority of these are wet-based systems that use a boiler and radiators to distribute heat around the home and most are gas fired, with an estimated 21.6 million gas boilers currently in use in the UK. Where gas is not available, oil fired systems have been increasingly used with current estimates suggesting there are around 1.4m installed, mainly in rural off-gas areas. The remaining 3.6 million homes use a combination of different technologies, including off-peak electricity.

Most homes (86%) also use their central heating boiler to provide hot water, either instantaneously through combination boilers or via a hot water cylinder. Given this dominance of gas for providing space heating, it is also the main fuel used to provide hot water. For cooking, fuel use is more evenly split, with people showing a preference towards gas hobs and electric ovens.

Factors influencing fuel and technology choices

Although it is often suggested that consumers' primary interest in energy is the 'service' that it provides, there is in practice a range of factors that influence people's choices for how their need for warmth, hot water and cooking are provided. Understanding the role that choice plays within decisions over fuels and technologies is complex and it is apparent that there is a limited amount of recent research available to help fully understand underlying preferences. In some cases, consumers have a limited choice, with two key factors being access to the gas network and type of tenure, although wider structure issues such as dwelling age and type, and household type undoubtedly all play a role in influencing the fuels and technologies which people have in their homes.

Space heating

It is clear that the desire for comfort plays a key role in influencing choice, with central heating now almost universally perceived to be an effective way to meet thermal comfort, not only in respect of average internal temperatures, but also the desire to heat a number of rooms simultaneously. High levels of satisfaction have been shown with central heating systems based on boilers and wet radiator systems, with lower levels of satisfaction shown for alternative technologies. Some of the issues explaining lower satisfaction were highlighted by Element Energy

[1] Hobs and ovens

(2008) and included the failure to reach the desired level of heat and/or hot water as and when needed, difficulties in controlling a system, unreliability, high maintenance, difficulty with obtaining parts and a preference shown towards having one system that can meet all a householder's needs.

With respect to fuel use, there has been a historic preference for gas, given that in comparison to other fuels its use for space heating has increased. There are a number of underlying factors that help explain this. In part this relates to comfort but also to capital and running costs, as it is apparent that consumers are seeking to spend no more than is necessary to get a system that meets all their needs. With the possible exception of Economy 7, the upfront capital and ongoing running costs of gas are lower than other fuels on an equivalent basis. Gas, then, is an established technology that is seen as reliable and familiar, and that is supported by a mature market, giving consumers choice over energy suppliers, makes and models of boilers and a large number of companies that can install and maintain the system.

Hot water

Given the close link between space and water heating, many of the points above equally apply to the provision of hot water. These include the high levels of satisfaction that are shown towards systems that are combined with central heating. However, there is some divergence in technologies and fuels specific to hot water. Although linked to heating, it is apparent that there is a growing preference for the use of combination boilers that can provide instantaneous hot water, with the added benefit for householders of saving space by removing the requirement for a hot water cylinder. With respect to fuels, gas is still the dominant fuel for hot water, although electricity plays a relatively bigger role in meeting hot water demand. This is likely to include the use of immersion heaters within some systems (some of which will be off-peak Economy 7). There has also been a growth in instantaneous electric showers.

Cooking

There is a preference for the use of gas hobs, linked to quick response and flexibility while for ovens there is a trend towards electricity, perceived to provide a more even heat. The data suggest that each of these preferences is likely to persist. This itself suggests that many homes may wish to continue to use both fuels for cooking. Microwaves also play an important role.

Future options for dealing with direct emissions from fossil fuels in the domestic sector

There are essentially two key mechanisms for reducing the direct emissions associated with the use of heat in the domestic sector. These are, firstly, and most logically, efforts to minimise demand as far as practicably possible through improvements to the energy efficiency of homes, maximising the efficiency of existing appliances, promoting the uptake of more efficient appliances and encouraging changes in energy use behaviour. Having reduced demand, the second option is to encourage the uptake of low carbon heat. Both face a range of challenges which vary with the type of housing and the type of household.

Policies to improve energy efficiency have a long track record and have been effective at bringing down the total level of energy consumption and emissions. However, there are still large parts of the stock that are not adequately insulated and there are a large number of appliances which are inefficient and/or are being used inefficiently. Understanding the reasons behind this has been a growing area of research, linking to attitude and behavioural studies, including behavioural economics, which show that people do not follow rational choice models: instead there is a tendency to discount future benefits, use defaults and be influenced by social norms (CO 2011). These not only limit the uptake of cost effective measures, but also influence people's energy use behaviour, with evidence to show that people are willing to do things only if the level of disruption or lifestyle change is limited and the quality of life remains similar. These insights create challenges for minimising demand and for encouraging the uptake of renewable heat.

It is suggested in the modelling and scenarios from the Committee on Climate Change (CCC) and DECC that there will be a limited role for biomass and solar thermal in the domestic sector, with the use of heat pumps growing most significantly from a current installed base of around 28,000 to 0.6 million by 2020, 6.2 million by 2030 and potentially some 19 to 27 million in 2050. It is also apparent that, whilst most research sees a role for renewable heat technologies in off-gas properties and for new homes in on-gas areas, to reach the targets proposed by CCC and DECC will also require uptake in the existing on-gas sector, in particular after the 2030s.

Which technology is most appropriate for any household or a particular dwelling will depend on a wide range of housing related factors, such as family size, income, tenure, dwelling size, location, access to gas, what technologies are currently being used, running costs, how satisfied people are with them, etc. It is also likely to depend on people's attitudes and understanding of different technology options and the amount of hassle or hidden costs associated with replacing a heating or hot water system. This will also link to wider attitude and behavioural issues.

Current studies into the use of renewable heat are fairly limited and have either focussed on the reasons for adoption or non-adoption, or have monitored the use of technologies that have been installed. Most of the research looks at off-gas housing and tends to contain two distinct groups of consumers. The first are those that have installed microgeneration themselves and have generally fallen into a niche market made up of either environmentally concerned, older, the relatively affluent, and/or technology enthusiasts. The second group is made up of social housing or other groups that have had the equipment installed at no upfront costs to themselves. Whilst these show that there are generally high levels of satisfaction across renewable heat technologies, they give only a limited insight into the potential issues for encouraging the uptake of renewable heat in on-gas households. Some of the issues highlighted within these studies, along with a further range of barriers identified through modelling work for the CCC, are summarised below.

Technology	Issues found	Additional barriers to uptake
All	• disappointment in the level of fuel savings achieved • issues with the amount of disruption caused during installation	• high upfront capital costs and long payback periods and a risk of projected declines in cost not being achieved • hidden and missing costs • lack of awareness or understanding of different options • lack of suitability, particularly in terms of energy efficiency of housing • consumer confidence in new technologies • lack of credible installers and suppliers and other supply chain constraints • hassle factors associated with having work done, or for ongoing operation • concerns about ease and costs of maintenance
Heat pumps	• concerns over running costs, although this in part may reflect the switch to one heating fuel or heating the whole home • mixed views on their ease of use and ability to control • concern over noise for ASHPs • lower temperatures than desired	• uncertainty over improvements in COPs • poor installation standards • high levels of maintenance • the need for high levels of energy efficiency • the potential need for new heat distribution • the need to dig up gardens for GSHPs • failure to meet hot water demands
Biomass	• difficulties in control • securing reliable fuel suppliers • perceived concerns over maintenance and hassle for fuel and cleaning	• space requirements for fuel and equipment • uncertainty on future fuel prices • sustainability of fuels • air quality issues
Solar thermal	• mixed views on their visual appearance • actual and perceived integration problems	• limited suitability – roofs and integration

With respect to domestic hot water, the trend away from the installation of hot water cylinders could in time close off one opportunity to integrate micro-renewable technologies and household-level thermal storage. Similarly, household cylinders could have a role in offering a thermal storage capability with respect to large-scale renewables on the electricity system, in particular wind at low-priced periods. It seems important to keep open such opportunities for both household and community-level storage potential.

Fuel and technology costs

Data from a range of organisations shows that consumers are concerned about, and take account of, the running costs of different heat technologies, factors that will play a role in influencing choice of fuel and technology. Currently both the capital and running costs for gas-based central heating systems are considerably lower than alternative renewable heat options. It is difficult to predict with any accuracy how prices may change in the future, but the relative future price of gas to electricity, along with the capital cost of technologies will play a central role in people's willingness to adopt renewable heat.

Recognition of inertia

The issues and barriers outlined, along with a growing understanding around attitudes and behaviour, provide further insight into the factors that influence how households take decisions on technologies and fuels for heat. This in turn may also offer insight on how consumers may act in the future. The evidence shows that people essentially seek technologies and fuels which are cost-efficient and affordable – to buy, install and run – and which are reliable, easy, and compatible with their current systems and lifestyles. The implication of this for creating a shift for households towards low carbon is that (1) there is a generally high level of satisfaction with gas (other perhaps than dissatisfaction on high fuel-prices generally) and (2) there is an effective 'default' to gas, manifested as inertia, in particular in on-gas households.

More generally, inertia already appears to limit the uptake of even the most cost effective energy efficiency measures and people's willingness to change behaviour and this is likely to be more pronounced for renewable heat. This reflects the high levels of satisfaction with the way that heat and hot water are currently provided and the evidence suggests that people attach a low priority to considering changes to heating systems (unless there are specific problems with the incumbent technology or fuel). It is also apparent that consumers seek to repair existing boilers when possible and, when not, replace them with a broadly like-for-like condensing model (given it is generally a distress purchase). Furthermore, the running costs of gas-based heating and the capital and operational costs for installing and maintaining gas boilers remain considerably lower than the alternatives – and are likely to remain so for the foreseeable future. Even in off-gas housing, the expectation that solid walls (prevalent in some off-gas areas) need insulation to enable the effective use of renewable heat, particularly heat pumps, adds further cost and can create issues both for visual appearance and/or levels of disruption. It is far from clear, in the models, scenarios and policies that have been developed so far, how easy it will be to address these issues and therefore how effective the drive to electric heat in the end will be, particularly in the case of existing, on-gas housing.

Overcoming inertia

One potential way to address the 'default to gas' is to work with natural intervention or trigger points, which also link to attitudes and behaviour. There is a range of studies that have examined these, primarily in respect to insulation, so the findings may not be entirely transferable to renewable heat. They show that there are some logical points where householders may uptake low carbon measures. The first is before or during renovation, repair or maintenance. Significant work takes place each year and with respect to energy efficiency measures, it is suggested by EST (2011b) that people are willing to extend their budgets to install them. However, many projects are comparatively small-scale, for single rooms for example, suggesting in terms of renewable heat that only the least disruptive technologies may be taken up, such as solar thermal or biomass stoves; and it is not clear how far people may be willing to stretch budgets for more expensive or far-reaching options.

The second intervention point is in the housing transaction market, which again is relatively large in terms of annual turnover, and can lead to potentially large renovation and refurbishment work, but may also include no work or smaller single-room projects. The potential to influence the uptake of renewable heat at this point is not clear as it may still face similar barriers to those highlighted in the table above. There is also likely to be some segmentation between the different types of buyer and therefore the willingness to make major changes to heating systems, with some evidence to suggest that currently both landlords and owner occupiers are wary of installing unconventional technologies in case it makes it harder to rent or sell.

Policy developments such as the Green Deal, ECO, RHI and FiTs could increase the opportunities that are available at these intervention points, overcoming the financial and behavioural barriers associated with low carbon measures and potentially increasing the suitability of homes to use renewable heat. The further work to deal with other key barriers around awareness (including Energy Performance Certificates (EPCs), consumer confidence and supply chain constraints) will be equally as important as financial incentives, particularly for encouraging the takeup of measures in sectors of the market that are outside of the intervention points above and/or are on-gas. It is far from clear how effectively the different barriers to energy efficiency and renewable heat will be overcome and, given the underlying approach from Government to develop market-based mechanisms, it will take some time to understand and evaluate the response from consumers and the wider manufacturing and installation markets.

A sustainable role for gas

There is considerable potential for rolling out renewable heat in off-gas homes, subject to their effective insulation, and even more so in the projected number of new builds up to 2030. However, post-2030 it is apparent that to reach the carbon targets, policy and modelling suggest that renewable heat will also need to penetrate existing on-gas homes. This raises two fundamental questions, firstly, given the high household penetration and satisfaction with gas, and the seemingly high levels of inertia in respect of home-heating, it is unclear what may prompt consumers to switch away from gas as their technology and fuel for heat. There is a significant gap between where consumers are now and where the modelling and policy suggests they will be post-2030, unless the prevailing economics of household heat change very significantly (i.e. significant changes in relative capital costs, running costs and fuel prices of gas and electric heat) or unless, increasingly, regulation starts to encourage consumer decisions in that direction (e.g. labelling, home EPCs, building regulations for both new property, existing property etc). Secondly, the considerable prominence that is being given to driving electrification of heat perhaps underplays the near-term and significant opportunities to maximise the efficiency of gas within existing homes pre-2020 and beyond. Given the potential for saving carbon, reducing fuel bills and improving levels of thermal comfort, more policy attention should be given to improving efficiency in on-gas households now, as part of the whole development of the UK's energy policy.

Conclusions

Based on the research questions from Scotia Gas Networks, we have analysed and considered a number of key issues regarding the fuel and technology choices for heat within the domestic sector. This has taken account of trends over the last 20 years to understand how heat requirements have been met, how heat is currently provided and how this may change in the future. From this it has been possible to examine some of the underlying factors that play a role influencing consumer preferences for heat. Based on Scotia Gas Networks' research questions we conclude that:

- gas is the dominant fuel for providing heat in the domestic sector and is likely to remain so for some time to come;
- a range of technologies are available to provide heat, but wet-based gas central heating dominates space and water heating, in the main areas in which gas is available;
- there is a wide range of factors that currently influence household fuel and technology choice for heat. Cost, comfort, convenience and inertia each have a significant role, particularly for space heating and to a lesser extent water heating preferences;
- consumer preferences could prove a significant barrier to the uptake of renewable heat.
- there is a lack of clarity about how government sees the role of gas evolving in the household sector through to 2030 and beyond.

Key findings and recommendations

Of the policies, measures and incentives that are in place and being developed to meet the UK's carbon and renewable energy targets, many will improve thermal insulation within the domestic sector, notably CERT, CESP, Green Deal and ECO. As such, towards 2020 policy will help to reduce demand for gas (and electricity) making their use more efficient and cost-effective for consumers. In the case of gas, these measures will also reduce the direct emissions from the domestic sector. However, further and significant near-term gas savings could also be achieved by the active promotion of additional cost-effective measures focused directly on improving efficiency of household gas use, particularly through better controls and quicker boiler upgrades.

Beyond increasing efficiency, it seems that other incentives, such as the RHI, FiTS, and Zero Carbon Homes, are currently more oriented towards the promotion of electricity, at the expense of gas, given that post-2020 and beyond; policy is seeking to encourage households to adopt electricity for heat. The scale of the anticipated step-up to household electrification post-2030 is substantial, as is the transition in terms of where we are today in terms of gas dominance of household space-heating and hot water. The aspiration level for electric heat implied by the UK's carbon targets, and Government acceptance of this direction of travel, is currently not underpinned by an economic analysis of the likely impact on households of a large-scale switch from gas to electric heat in the 2030s, nor by an evaluation of the likely role of customer preference and choice.

Given where we are today, questions arise as to how readily achievable the shift to greater electrification may be. Up to 2030, interventions and incentives need to take more account of the potential to achieve substantial carbon savings from household gas savings. Any such savings will also have a knock-on impact on (1) the comparative economics of eventual household substitution from gas (including renewable gas) to electricity (2) likely customer choice and (3) the residual level of carbon savings achievable from electrification of heat. Significant household gas savings pre-2020, could influence the comparative cost-efficiency of uptake of low-carbon and renewable electricity technologies for households longer-term.

The UK needs to decarbonise its economy and this requires action within the domestic sector. However, options in respect of domestic heat need to be kept open and fully explored, before locking into a system that householders may find unappealing. The risk is that existing households may become a significant hurdle to a more electric future for heat which in turn could impact on the UK's ability to meet its 2050 target. The majority of domestic consumers use gas, because it is in place and because customers are generally broadly satisfied with relative price, convenience and comfort. The focus of policy is on carbon, but from a consumer perspective this risks an unsolicited choice for the longer-term between electricity and gas. Gas, and the technology that supports it, is understood and liked, whereas alternatives may face teething problems plus cost and other barriers. A first step must therefore be to give priority to measures that maximise the efficiency of gas, particularly as household gas use currently accounts for around 14% of all UK GHG emissions. This could include upstream measures to reduce losses and make more use of biogas, which would also help to avoid the range of barriers associated with alternative forms of renewable heat, as well as the very considerable downstream scope with respect to replacing inefficient boilers, installing better controls and supporting the development of newer technologies. Until the picture for technology and fuel choice for household heat is both better quantified and better understood from a consumer perspective, there is a risk that more expensive pathways to decarbonisation are incentivised at the expense of alternatives which may be both cost-effective and attractive from a customer viewpoint. Near- and medium-term investment decisions – both by actors in the gas sector and by individual households – need to be underpinned by a more strategic view of the role anticipated for gas in the UK energy system in the future, including for household gas.

Based on these findings we suggest that:

- there is a need for further direct work with consumers to understand their underlying preferences towards the provision of heat, hot water and cooking, in particular in on-gas housing;
- there is a need for further analysis, including likely cost and emissions savings, based on a more efficient role for gas within the domestic sector;
- there is a need for further work on how customer preferences will have an impact on the various Government models;
- Government has a central role in directly communicating the potential changes in how consumers may meet their heat needs in the future;
- Ofgem should carry out further work around consumer preferences with respect to heat through their consumer panels.

1. Introduction

This research reviews the literature and evidence surrounding consumer choice regarding the fuels and technologies used within the domestic sector for space heating, hot water and cooking. It has a particular focus on the role of gas. The work was commissioned by Scotia Gas Networks. The authors of this paper are wholly responsible for the content, analysis and conclusions. The work is based on the following research areas:

- What are the main fuels and appliances for heating, hot water and cooking in homes?
- What are the main determinants in making these choices? What characteristics of (1) gas (2) oil and (3) electric (on-peak & off-peak) heating do customers particularly like or dislike and what are the reasons?
- Do consumers have a preference for the use of gas cooking compared to other cooking technologies and if so, what are the reasons?
- Do consumers seek any particular characteristics or have any preferences when thinking about how their heating technologies are going to change in the future?
- Is there any emerging evidence describing levels of consumer satisfaction with renewable heating technologies such as heat pumps, solar thermal, biomass boilers?

The rest of this report examines a number of key areas regarding these questions and considers them against the wider debate, pathways and scenarios which examine the kind of energy system that may be developed in order to meet the UK's climate change and renewable energy targets. The main focus of the research is possible development to 2020 and 2030. The report does not consider the role of electricity in providing low carbon transport. The structure of the report is as follows:

- Section 2 sets out an overarching context for the work, considering the current patterns of heat consumption in the domestic sector and the emissions associated with them. It then considers the transition of the UK towards a low carbon economy, looking at the CCC recommendations to 2020 and 2030 and the policy developments that have emerged to deliver them.
- Section 3 looks at energy trends in the domestic sector, considering total consumption and fuel use and some of the underlying factors that influence them. It then considers the technology and fuel use for space heating, hot water and cooking.
- Section 4 examines what factors may influence consumer choices in respect to technologies and fuels, considering current levels of satisfaction, the role of cost, the impact of inertia, the opportunities for intervention and studies into attitudes and behaviour
- Section 5 looks at the options for dealing with direct emissions associated with the use of fossil fuels for providing heat within the domestic sector, considering technologies for renewable heat, evidence of consumer satisfaction for these technologies, the barriers to uptake and the opportunities for increasing gas efficiency.
- Section 6 brings together these findings to answer Scotia Gas Networks' research questions and considers the implications of future energy pathways for providing space heating, hot water and cooking.

2. Context

This section puts the research questions into the wider context of current domestic energy use and emissions. It examines how UK energy policy has developed over the last decade and discusses the emerging energy pathways towards 2050, particularly those used by the CCC and DECC. Finally, it focuses on what the policies and pathway analysis suggest may happen within the domestic sector, particularly for dealing with direct emissions (i.e. non-electricity) and their reduction through action on energy efficiency and low carbon heat.

2.1 Current domestic energy consumption and emissions

Total final energy consumption in the UK domestic sector stood at around 45.5 million tonnes oil equivalent (mtoe) in 2008[2], representing 27.5% of the UK's total final energy consumption (NS/DECC 2009). The breakdown by fuel and end use for 2008 is shown in Figure 1 and Table 1, showing that gas accounted for 68% of demand. In just considering heat (i.e. space, water and cooking), these collectively accounted for 84% of final energy consumption in the domestic sector. Breaking these data down further (Figure 2) shows that 97% of the heat consumption was for space and water heating (36.98 mtoe), of which 82% of the consumption is met through the use of gas (30.24 mtoe), with the respective share for space heating being 83% (21.89 mtoe) and for water heating 78% (8.36 mtoe). Cooking makes up a much smaller proportion of final consumption, where fuel use is split almost equally with electricity (1.30 mtoe).

In looking at the total emissions, the CCC suggests that the domestic sector accounted for 23% of the total UK greenhouse gas (GHG) emissions in 2008[3], with 56% of CO_2 emissions coming from direct sources (i.e. non-electricity – mainly heat) and 44% from indirect emissions (i.e. electricity consumption) (CCC 2010). However, given that indirect emissions are already capped upstream through the EUETS, this report only focuses on the direct emissions for which the domestic sector is responsible, with HMG (2011a:24) stating that in 2009 "The UK's 26 million homes are responsible for 14% of its greenhouse gas emissions". It will be the efforts to tackle these that will lead to additional emissions savings in the domestic sector pre-2020 and, given the current dominance of gas, this clearly has implications for the current use of this fuel within homes and the technologies that use it.

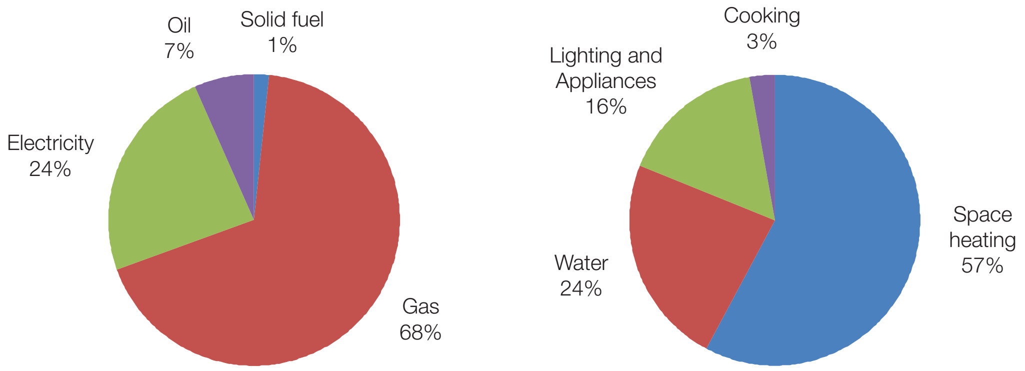

Figure 1: Delivered energy by fuel and end use 2008. Source: NS/DECC (2010: table 3.7)

[2] The figure for 2009 is 43.59 mtoe which was 28.5% of the UK's total final energy consumption. 2008 data have been used as these are the latest available that gives a breakdown by end use in the domestic sector.

[3] Given that emissions from power generation are already capped upstream in GHG accounting terms, excluding them reduces the total GHG emissions from the residential sector (DECC 2009). For example in 2009 emissions by source within the domestic sector were estimated at 78.6 MtCO2e, or nearly 14% of the UK's total emissions (NS/DECC 2011a).

	Gas	Electricity	Oil	Solid Fuel	Total
Space heating	21,887	1,455	2,305	596	26,244
Water	8,357	1,501	725	155	10,738
Cooking	668	625	3	3	1300
Lighting & Appliances	3	7,236	-	-	7,239
Total	30,916	10,818	3,033	753	45,521

Table 1: Delivered energy by fuel and end use 2008[4] thousand tonnes of oil equivalent (ttoe)
Source: NS/DECC (2010: table 3.7)

2.2 Household data

A central component in understanding fuel and technology choices for heat and the emissions that are associated with them relates to the current and future housing stock. Of the estimated 26 million households within the UK, it is suggested that around 84% of these are on the gas network (HHWT 2010), meaning around 4 million are off-gas. Projecting how this stock may change going forward is highly uncertain, reflecting changes to population, household sizes (CCC 2010) as well as the net gains in housing that occurs every year – i.e. the number of demolitions and the number of new builds, as well as conversions, all of which in themselves can be influenced by a wide range of economic and social factors. Using data from CLG (2010), the HWWT (2010) and CCC (2010), possible projections for future housing suggest that:

- by 2020 there could be around 29 to 30 million households, which would include around 27m existing homes and up to 3m new homes;
- by 2030 the number of households could rise to 33 million of which around 3m would be new build.

2.3 The transition to low carbon

Over the course of the last decade, EU and UK developments in energy policy have increasingly sought to balance the not necessarily complementary challenges of reducing GHG emissions, whilst ensuring energy security and affordability (Platchkov et al 2011). Policy and targets to enable these goals to be met have been set out in a range of white papers, consultations and legislation over the last decade.

Within the UK, a new approach to energy policy, since privatisation was set out in the 2002 PIU report, which put forward a new framework and was followed by a new energy white paper in 2003 and a further review in 2006, with further white papers in 2007, 2009, 2011. Across these developments the central goals of GHG emissions reductions, reliable supplies and affordability, have been consistent, along with a policy of achieving them through competitive markets. Increasingly, development at the EU level has also begun to play a greater role in shaping UK policy; a key development in the last decade was the 2007 Energy and Climate Package

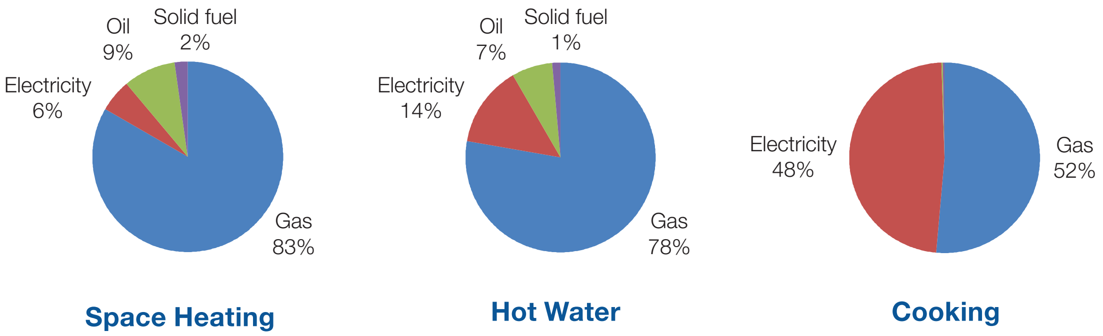

Figure 2: Final UK energy consumption by end use and fuel. Source: NS/DECC (2010: table 3.7)

[4] The data on end use are from DECC data that is modelled by BRE, and as such they only provide an estimate of underlying trends.

(CEC 2007) which put forward the 20-20-20 goals, which set targets for reducing GHG emissions by 20% on 1990 levels and increasing the proportion of renewables in the energy mix by 20%, as well as setting wider goals to reduce energy consumption by 20% and increasing the use of biofuels in vehicles by 10%, all by 2020 across Member States.

As well as committing to a 15% target for increasing the share of renewable energy (across electricity, heat and transport) by 2020, there is cross-party support in the UK to take a global lead on efforts to reduce GHG emissions, by introducing legally binding targets to reduce emissions by 80% by 2050 (against a 1990 baseline) through the 2008 Climate Change Act (DECC 2011a). Included in this is the introduction of the five year ‘carbon’ budgets to move towards the 2050 target, with the first three budgets starting in 2008 and covering policy to 2022. To provide Government with advice on the levels of the budgets and the possible ways to meet them, the independent CCC was established in 2008. In their first report the CCC recommended an interim budget for reducing emissions by 34% by 2020 and an intended budget for reducing emissions by 42% by 2020 (both relative to 1990) and highlighted the need for action across all sectors (CCC 2008). The Government subsequently produced the Low Carbon Transition Plan (LCTP) to set out their approach for meeting a 34% cut in GHG emissions (HMG 2009a) and this was published alongside a range of other strategies including a Renewable Energy Strategy (RES) which set out the approach for meeting the EU 15% renewable energy target and suggested that 30% of electricity, 12% of heat (including biomass, biogas, solar and heat pumps) and 10% of transport energy would need to come from renewable sources by 2020 (HMG 2009b). During 2009, Ofgem also released their first analysis of the levels of investment that would be needed in the UK’s energy infrastructure to meet the climate change targets and ensure energy security, suggesting that up to £200 billion may be needed in the next 10 to 15 years (Ofgem 2009).

A mix of binding targets and non-binding interim goals had therefore emerged, driven primarily by the need to reduce GHG emissions and meet the renewable energy target. Increasingly the focus has shifted towards the possible ways to achieve them. A range of models and scenarios to investigate the possible technology mixes and resources has therefore been developed, including their assumed economic and emissions impacts (Speirs et al 2010). This included the 2008 CCC report, which set out how a portfolio of different technologies could deliver the recommended emission reductions to 2022 which, along with the need for energy efficiency improvements in buildings (and industry), suggested that a key feature of an optimal path will include almost full decarbonisation of electricity generation and the extension of electricity to a wider range of energy end uses, in particular transport and heat (CCC 2008) – an approach reiterated in the recommendations for the Fourth Carbon Budget covering much of the 2020s (CCC 2010). The Government’s own modelling and policy approaches, within the LCTP, mirror many of the CCC recommendations in respect of the approach to reach the targets and these were underpinned in part by several scenarios, mostly using versions of the UK MARKEL model including work undertaken for the CCC, UKERC’s 2050 study, DEFRA and DECC itself (Speirs et al 2010:2). Over the first four carbon budgets, and in order to be on a pathway capable of delivering the binding 2050 target, this body of analysis is characterised by a shift towards a more electric-centric energy system, or an ‘all electric future’ (Speirs et al 2010).

Subsequent work by DECC through their 2050 Pathways Analysis, which initially provided six illustrative pathways to consider what may be physically and technically possible in different sectors (HMG 2010) and later a further 17 illustrative pathways, found that common themes across the different pathways included the need to cut energy demand, decarbonise the power sector and substantially increase the use of electricity in heating, transport and industry. This would potentially see a doubling of electricity demand by 2050 (HMG 2011b). As Speirs et al (2010) suggest, the 2050 pathways work therefore further reinforced an evolving orthodoxy of an ‘all-electric future’. Further analysis of different model runs from six different reports that looked to 2050 (including CCC and DECC) also found some commonality in the drive to decarbonise the electricity system to enable the UK’s carbon and renewable energy targets to be met (Moore 2011).

Some alternative views to an increasingly electric future are also emerging, which includes the Speirs et al (2010) research, which specifically considers the delivery of heat. It highlights how a large fraction of waste heat is lost from primary energy production and that there could be power flow challenges, particularly for winter peak demand, with some approaches to electrify heat. By examining an all-electric future from a power flows perspective, they suggest an integrated scenario that makes use of waste heat through the creation of heat networks which, in combination with CCS and biomass fuelled plants and CHP, would have the benefit of enabling deep emission cuts and avoiding peak electricity loads on the system. They also highlight that there are difficulties with whichever low carbon future is pursued and that there would be merit in examining the issues with each approach to encourage diverse solutions, particularly for low carbon heat.

In addition, a recent analysis by Redpoint for the Energy Networks Association, which draws heavily on the 2050 Pathways analysis, suggested that there were credible and robust scenarios in which gas could play a major role in the GB energy mix whilst meeting the 2020 renewable targets and 2050 carbon targets. It highlighted the value of a stronger gas future compared to higher electrification scenarios in terms of cost-effectiveness, suggesting that such an approach could save almost £700bn over 2010 to 2050 on a net present value basis. This reflects comparatively lower costs of investing in and maintaining the existing gas network infrastructure, compared to total system costs for alternative approaches, giving a strong economic rationale for a higher gas future (Redpoint 2010).

It is apparent that all the modelling and views emphasize that there is a degree of uncertainty about the future (Moore 2011) and both the CCC and DECC highlight that options need to be kept open and a portfolio approach is required in moving toward the goals for 2050.

2.4 Recommendations for meeting the targets to 2020 and 2030

The CCC suggests that rapid decarbonisation of the power sector is required, with the emissions projected to fall from around 560gCO_2/kWh to 350gCO_2/kWh by 2020 and 50gCO_2/kWh by 2030, partly reflecting the opportunities that are offered from the closure of some of the current generation fleet (CCC 2010). This decarbonisation provides the rationale for developing the use of electricity into the domestic sector beyond 2020 as the direct emissions currently associated with the use of heat can be avoided. In addition, another important component is the need to improve energy efficiency as: it has the potential to make significant contributions to meeting the carbon budgets by reducing household gas demand; it reduces consumption and bills, helping to offset higher energy prices; energy-efficient homes are required for the successful deployment of heat pumps; and, for the 2020 renewable target, reducing demand will require less supply-side investment (CCC 2011:119).

2.4.1 Reducing direct emissions to 2020

The CCC's first report in 2008 highlights the potential for significant energy efficiency improvements at little or no cost to the economy or individuals, as well as a range of options for low carbon energy but at a higher cost. To estimate the potential savings, a range of modelling and analysis techniques was used, including Marginal Abatement Cost Curves for over 50 measures, the potential for lifestyle change, possible barriers to action and evidence from social sciences on people's willingness and ability to act. The CCC provide a breakdown of potential emissions savings ranging from theoretical technical potential, cost-effective potential, through to realistic potential[5] (CCC 2008).

For energy efficiency, the CCC analysis predominantly focuses on existing buildings as these are expected to make up around 99% of housing stock by the 2020s. The scope of possible energy efficiency measures includes: adding and upgrading loft insulation; cavity wall insulation; solid wall insulation; replacement of existing boilers with efficient 'A'-rated condensing boilers; uptake of energy efficient wet and cold appliances; and energy efficient lighting. They also suggest that modest lifestyle changes could include: turning down thermostats by 1°C; washing clothes at lower temperatures; and switching off unused lights. Whilst the technical potential from all these measures is as high as 43 MtCO_2, they suggest that the realistic potential lies between 9 MtCO_2 (current ambition[6]) to 18 MtCO_2 (stretch ambition) in existing buildings and 4 MtCO_2 from new buildings[7] (CCC 2008).

The CCC also considers the options for reducing emissions through the production of renewable electricity and heat at a local level, using a similar iterative process to that of energy efficiency. This included examining the technical potential and cost for small wind, PV, upgrading boilers to CHP, solar thermal, biomass heating, heat pumps and district heating. To consider the realistic potential, the CCC consider people's willingness and ability to install measures due to a range of constraints (financial, hidden costs, lack of information, fear of unknown, etc) alongside evidence from Element Energy that suggested levels of uptake will not be significant to 2020, even with upfront financial support (CCC 2008:235). The CCC suggested that the realistic potential in the domestic sector ranged from no savings under the current ambition through to 10 MtCO_2 in the extended and stretch ambitions by 2020 (CCC 2008).

With respect to possible measures through the 2020s and reflecting policy developments since, the Fourth Carbon Budget provided an overview of what could be installed by 2020 in the domestic sector:

- insulation of 90% of lofts and cavity walls takes place;
- two million solid walls are insulated;
- 13 million boilers are replaced with new efficient boilers;
- substantial increases in appliance efficiency are achieved;
- heat pumps are installed in around 0.6 million homes;
- less than 0.1 million biomass boilers installed (CCC 2010).

[5] Theoretical potential – abatement potential that could be achieved in the absence of any barriers to the uptake of measures; Cost effective potential – abatement potential that costs less per tonne of carbon saved than the projected carbon price; Realistic potential – technical potential adjusted to reflect barriers to uptake of measures and ways that these might be addressed by the policy framework (CCC 2008).

[6] Current Ambition includes measures which would cost less per tonne than the forecast carbon price, and/or which are covered by policies already in place; Extended Ambition incorporates more ambitious but still reasonable assumptions on the penetration of energy efficiency improvements and a number of measures which would cost appreciably more per tonne of carbon abated than the predicted carbon price; Stretch Ambition adds further feasible abatement opportunities for which at the moment no policy commitment is in place (CCC 2008: xxvii)

[7] This appears to be based on a CLG abatement estimate as a result of the zero carbon homes policy, as of 2008. The final definition for zero carbon homes was not agreed until 2011, so this figure may no longer be accurate.

2.4.2 Reducing direct emissions to 2030
The Medium Abatement Scenario in the Fourth Carbon Budget sets out what the CCC think should be planned for in the 2020s, on the basis of feasibility, sustainability and cost-effectiveness. They suggest that there could be up to 7 million new homes by 2030 along with ongoing demographic changes, which could increase emissions in the domestic sector by up to 20 $MtCO_2$[8] ; existing stock is expected to account for 90% of the housing stock by 2030.

In respect to energy efficiency, the CCC anticipated that by 2020 there could have been widespread uptake of loft and cavity wall insulation meaning the focus would need to shift towards internal and external solid wall insulation. They suggest that a further 1.5 million homes could have solid wall insulation by 2030, which would reduce heat demand and support the deployment of heat pumps. They also highlight the scope for further improvements through more difficult and expensive measures such as floor insulation and energy efficient glazing; with further savings coming from the growing uptake of energy efficient appliances (CCC 2010).

For low carbon heat, the CCC suggest that the options for reducing emissions in the 2020s include heat pumps, bio energy and district heating and this is modelled from a technical and economic perspective. For heat pumps, the CCC consider air source (ASHP), ground source (GSHP) and heat pumps with storage and suggest that in the 2020s around 6.2 million homes could have heat pumps installed. Further scope for emission reductions could come from bioenergy, including the use of biomass, although issues of sustainable sourcing and air quality lead them to suggest there is a limited cost-effective role for them within the residential sector, with scope for around 0.9 million biomass boiler installations by 2030. For biogas, there are a range of options, including injection into the grid, which could help bring the overall carbon intensity of gas down, although it is not clear if this would be the best use of this resource. The CCC is due to report on in more detail on bioenergy later this year (CCC 2010).

In their review of renewable energy in May 2011, the CCC highlight the need for support to enable significant deployment of renewable heat by building up the supply chain and improving consumer confidence, suggesting an overall target of renewable heat penetration of 12% in 2020, increasing to 35% by 2030 – Figure 3 (Medium Abatement Scenario). This figure also shows the important role of energy efficiency in reducing direct emissions, particularly in the 2020s.
Based on the projected number of new builds and the number of off-gas homes, much of the anticipated uptake of renewable heat is likely to happen within these parts of the housing stock up until 2030. However, post-2030, the CCC suggest that heat in buildings will need to be almost fully decarbonised by 2050 to reach the 80% emissions target. As well as making further improvements to fabric insulation and possible some resistive heating, the CCC suggest that the use of ASHPs and GSHPs could meet 55% to 75% of residential heat demand by 2050 (CCC 2010). Given that it has been suggested that 85% of the existing housing stock could still be in use by 2050 (Killip 2008), it will increasingly be necessary to work with on-gas housing. It is our understanding that DECC is in the process of creating a new Heat and Industry Directorate which amongst other things will carry out its own heat modelling, looking at possible uptake rates for heat pumps.

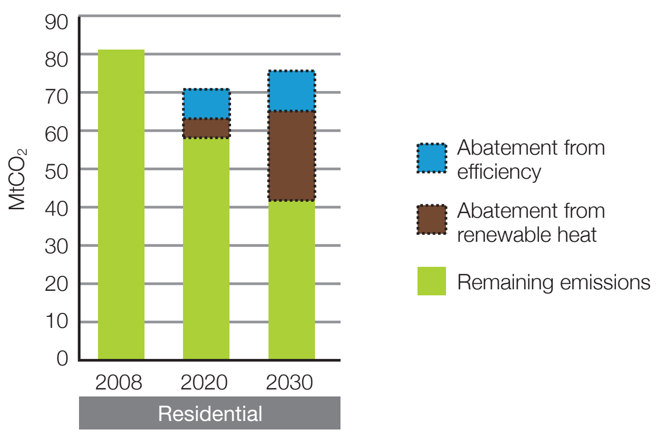

Figure 3: Medium scenario for residential direct emissions (2008, 2020 and 2030). Source: CCC (2011:121)

[8] The CCC suggest that some of this increase will be offset by new zero carbon homes, although this may be subject to the point above.

2.5 Policies to deliver the targets

Following the production of the LCTP and RES a range of policies has therefore been developed to work towards the delivery of carbon budgets and renewable energy target. This has included amendments to existing policies and legislation as well as new policies aimed at improving energy efficiency and driving decarbonisation. These will all have implications for the way that gas and electricity will be used, in particular for heat, in the future. At the same time a central strategy of Government is to create certainty for large scale low-carbon electricity generation, as a key component of meeting the renewables and carbon targets. (DECC 2011h:8).

2.5.1 Improving energy efficiency

Policies to improve energy efficiency reduce total consumption and, in the case of gas, also reduce direct emissions[9], subject to any rebound effects. They include:

- supplier obligations, such as CERT and CESP which are due to run until the end of 2012, which support a range of measures, fuel switching and to a lesser extent microgeneration (around 61% of measures under CERT have been for insulation (Ofgem 2011a) and under CESP the figure is 53% (Ofgem 2011b)). These are to be replaced by a new Energy Company Obligation (ECO) that will be targeted at helping the most vulnerable households and the housing stock that is hardest to treat, such as solid wall and off-gas properties (DECC 2011b);
- the Green Deal, which aims to enable the upfront costs of measures to be recouped through energy bills, subject to the 'golden rule'. It is hoped that by enabling consumers to install measures without the need to cover upfront costs, the Green Deal will help to overcome the known issue with the way the people discount future rewards, which results in inaction (CO 2011)[10]. The range of measures could cover heating, ventilation and air conditioning; building fabric; lighting; water heating; and microgeneration (DECC 2011c);
- building standards, including building regulations, zero carbon homes policy[11], the Code for Sustainable Homes and EPCs (Hoggett 2008). These have been subject to ongoing revisions since their introduction and the Government is increasingly seeking to make more alignments between these policies and other policies, such as the Green Deal (DECC 2011c), as well as trying to streamline the whole process to cut red tape for developers (Shapps 2010). It is suggested that as the wider policy to decarbonise electricity starts to reduce the carbon intensity of the grid, it will become easier to reach Carbon Compliance through the installation of electrical heating, over gas (ZCH 2011).

2.5.2 Decarbonising electricity

There is a large number of different policies focused on the electricity market, designed to deliver the targets for reducing GHG emissions and renewable energy. These include a mix of incentives to encourage increasing amounts of low-carbon and renewable energy generation, as well as legislation to encourage decarbonisation through taxes and caps on emissions within different sectors:

- the Renewables Obligation which aims to increase the amount of renewable electricity generation which is currently due to run (for grandfathered schemes) until 2037 in GB;
- the feed-in tariffs (FiT) for schemes up to 5MW which provide a guaranteed payment for both the electricity generated and exported, with differentiated tariffs offered to different technologies;
- the EUETS which is the principal mechanism for reducing emissions in the electricity sector, currently in its second phase, with the third phase due in 2013 and running to 2020 (DECC 2011d);
- the Climate Change Levy which taxes non-domestic energy users for lighting, heating and power, based in part on the carbon content of fuels, with the income recycled back to business through a cut in national insurance contributions and used to support energy efficiency and low carbon technologies (energy intensive industries can obtain a 65% discount through a Climate Change Agreement (CCAs) (DECC 2011e);
- the CRC Energy Efficiency Scheme, effectively a tax, which aims to cover CO_2 emissions not already covered by the EUETS and the CCAs, which encourages energy efficiency and cuts to emissions in large electricity users in the public and private sector;
- the CCS demonstrations for coal and gas fired generation;
- the new Energy White Paper, following the Electricity Market Reform (EMR) consultation, which seeks to attract investment, reduce the impact on consumer bills, and create a secure mix of low-carbon electricity sources including nuclear, renewables and CCS for fossil fuels. Key elements of the package include: putting in place a carbon floor price; introduction of long-term contracts (FiT with CfD); an Emissions Performance Standard set at 450g CO_2/kWh; and a potential Capacity Mechanism to address security and flexibility in the electricity system. The White Paper is a first stage in an ongoing reform process and there are still elements to be confirmed. The aim is to legislate by spring 2013 (DECC 2011j);
- Carbon Price Support was set out in the Finance Act 2011.

[9] Emissions for electricity are already capped upstream via the EUETS

[10] Although principally a mechanism to encourage energy efficiency, it is intended that microgeneration will be integrated into the scheme so that there is one package offering a whole house approach

[11] The latest definition just covers regulated emissions – fixed lighting, ventilation and space and water heating (CLG 2011), i.e. around two thirds of the total emissions from households (UKERC 2011).

2.5.3 Low carbon heat
In comparison to the policy measures and market interventions for low-carbon electricity, policy attention on renewable heat has only emerged recently (Conner 2008). The principal mechanism to encourage uptake is the Renewable Heat Incentive (RHI) which aims to increase the level of renewable heat from a range of technologies[12] from around 1.5% of total heat demand currently, to a level of 12% by 2020 (DECC 2011f).

The first phase of the RHI will launch later in 2011 and include limited support for the domestic sector via a Renewable Heat Premium Payment using around £15 million of central government funding. This will cover a range of technologies across all regions of GB and include households using gas and other fossil fuels, although it may be directed more towards off-gas houses. The second phase of the RHI will provide long-term tariff support for the domestic sector and will be introduced alongside the Green Deal in 2012. A wider range of technologies may be supported in the second phase of the RHI (DECC 2011g).

2.5.4 Further policy developments
Further policy developments to support the greater uptake of microgeneration are set out in the Microgeneration Strategy, which includes an action plan to help industry address the non-financial barriers to enable faster growth and uptake of small-scale low carbon technologies (up to 50 kW for electricity and 300 kWth for heat) and covers action around the quality of equipment and installation, skills in the supply chain, technology development and information and advice to consumers (DECC 2011h).

DECC also produced their renewable energy roadmap in July 2011, setting out the role of renewables in decarbonising the energy sector by 2030, along with nuclear, carbon capture and storage, and improvements in energy efficiency. It initially focuses to 2020 and the delivery of the UK's renewable energy target, seeking to identify current constraints that need to be addressed to enable deployment. Its principle focus is on those technologies that offer the greatest potential to 2020 (on and offshore wind, marine energy, biomass electricity and heat, ground source and air source heat pumps; and renewable transport) (DECC 2011i).

The development of a smart electricity grid to facilitate two way power flows in the distribution network is also part of the emerging policy landscape, with the need for a bigger and smarter electricity grid highlighted in the LCTP (HMG 2009a) and in DECC's Annual Energy Statement, with action initially focussed on the installation of smart meters in the domestic sector (DECC 2010b).

The legislative framework to implement a number of these emerging policies is set out in the latest Energy Bill which includes the legislative framework for: the Green Deal; new powers to improve energy efficiency in the private rented sector; the ECO; smart meters; measures to improve energy security; and measures to enable low carbon technologies (offshore wind and nuclear) (DECC 2010b).

The Government is also due to formally set out their strategy for reducing emissions in the 2020s to 2030s, in response to the CCC Fourth Budget Report. This is due in October 2011, although many of the policies that could play a role are being implemented, including the Green Deal, RHI and the EMR.

[12] The first phase includes: biomass, solar thermal, ground and water source heat pumps, on-site biogas, deep geothermal, energy from waste and injection of biomethane into the grid (DECC 2011h).

3. Energy Trends in the Domestic Sector

This section considers the long-term changes in energy demand in the UK domestic sector with respect to fuels and end uses, as well as some of the underlying factors that have influenced them. It then goes on to consider the fuels and technologies that are used to provide space heating, hot water and cooking, expanding on the data in section 2.1. The data are primarily derived from the domestic tables of energy consumption in the UK and covers the whole of the UK. In some cases data are only GB specific, although the difference between energy use in the domestic sector of GB and the UK is small (2% to 4%) and fairly constant (Utley & Shorrock 2008). Also, in the case of most of the more detailed analysis, this comes from the English Housing Condition Survey (EHCS), so only relates to England. It is made clear in the text, figures and tables which geographic level the data relate to.

3.1 Total household energy consumption

Trends in total energy consumption by fuel and end use within the UK domestic sector since 1990 are set out in Figure 4[13] and Figure 5. Over this period total consumption increased by around 7% (NS/DECC 2010): however, there has been a downward trend in total consumption since 2004 and this reflects changes in demand for different fuels. Final fuel use within the domestic sector is dominated by gas, but since 2004 it has significantly declined (subject to some weather related peaks)[14]. Consumption of solid fuels has also been in decline, whilst the use of household electricity for non-heat purposes has increased. Looking at end use, consumption is dominated by space heating, accounting for nearly two thirds of final energy use in 2008, although this has been declining. Of the other end uses the most significant change has been in final consumption for lights and appliances, such as consumer electronics, IT and small personal appliances[15]. These trends in final energy use show that, although total energy use per household has been declining since 1990 (mainly heat), total consumption per person has been increasing (mainly electricity).

[13] Excluding heat sold (less than 50 ttoe)

[14] This reflects growing levels or thermal insulation, increased boiler efficiency, etc, and as such it seems likely that domestic gas demand is pretty much saturated and as such has peaked.

[15] Some of the growth in lights and appliances will have been offset by improved efficiency in white goods, lighting, etc.

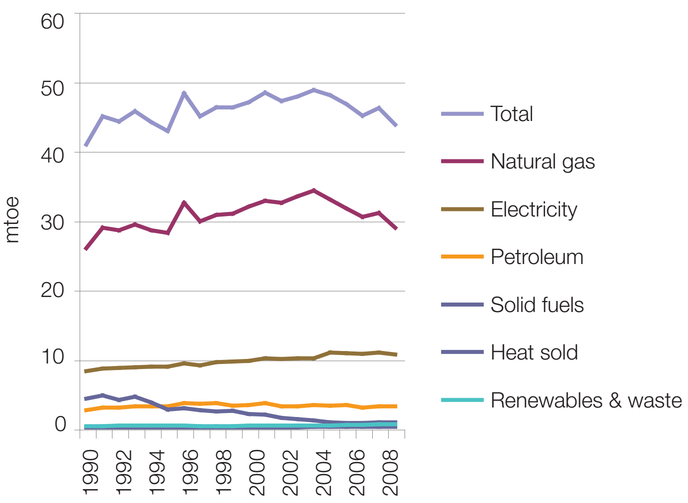

Figure 4: Final UK domestic energy consumption by fuel type. Source: NS/DECC (2010: table 3.1)

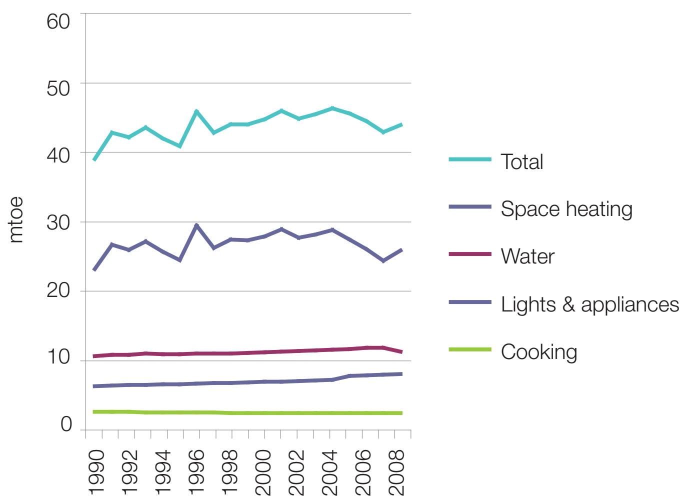

Figure 5: Final UK domestic energy consumption by end use. Source: NS/DECC (2010: table 3.6)

In terms of emission trends, the CCC highlight that in the residential sector they fell by around 4% between 1990 and 2006 mainly as a result of a decline in indirect emissions, whilst direct emissions have remained broadly level (CCC 2008). In their fourth budget the CCC highlighted that in 2009 emissions fell by 5%, mainly as a result of fuel price rises and the recession (CCC 2010). The trends in emissions and energy use (total and by fuel) are influenced by a range of underlying factors that are described below, relating to household numbers, changes in population, external and internal temperature trends, the growing use of appliances and improvements in the levels of insulation.

3.1.1 Housing and population

The total number of households since 1970 has increased by around 7 million, standing at around 26 million in 2009 (NS/DECC 2010; HMG2011a). It is also suggested that there are an additional 0.5 million dwellings above this level, that about 1.5% of the stock was vacant for 6 months or more and, excluding those that are rented out, around 1% of the stock are second homes (HHWT 2010). Over the same period, the UK population increased by 6.2 million to reach around 61.8 million in 2009 (NS/DECC 2010) and it is anticipated that this will increase to around 71.1 million by 2031 (ONS in HHWT 2010).

The fact that the number of households has grown faster than population reflects a trend towards smaller household sizes (Utley and Shorrock 2008; ONS 2010), between 1971 and early 2009 the average number of people per household decreased from 2.9 to 2.4, associated with an increase in the number of lone parents, smaller family sizes and more one person households (ONS 2010). By 2050 this figure is estimated to fall to around 2.1 (CLG in HHWT 2010).

The rising number of total (smaller) households is one of the factors that explain why total energy consumption from the domestic sector has increased (i.e. from per capita energy use), whilst total energy use per household has decreased (Utley and Shorrock 2008).

There is a wide range of other variables linked to housing, such as the age, type, tenure and location, that can all influence total energy use within the household, as well as the type of fuel and technologies that are used (BRE 2007):

- Data on the GB stock profile suggest that 36% of housing was built before 1939, 38% between 1939 and 1975 and 26% after 1975 (NS/DECC 2010). Broadly speaking, the older the property is, the less energy efficient it is (HHWT 2010), reflecting the fact that improving requirements under Building Regulations result in newer buildings, and older buildings that are converted into multiple dwellings, having better levels of thermal performance (Utley and Shorrock 2008). The age of a building can also have an influence on the type of system used for space and water heating (BRE 2007).

- There has also been a shift in tenure type, since 1970, towards owner occupation (Utley and Shorrock 2008) with the latest data for the UK showing that 17.5 million households were classified as owner occupied in 2009 – nearly 66% of the total stock (ONS 2010). As owner occupiers are directly responsible for the thermal performance of their property, it is suggested that they are more likely to invest in energy saving measures, compared to the private rented sector (Utley and Shorrock 2008); a similar relationship is likely to exist for other measures, such as microgeneration. In the rented sector, over the last decade the number in social housing has fallen, standing at 4.5m in 2009, whilst the number in the private rented sector has been increasing, currently standing at 3.8m (ONS 2010). Within social housing, driven in part by the Decent Homes Standard, the HHWT (2010) suggest that this sector now has the highest level of energy efficiency of all the stock. There are also links between the type of tenure and the type of technologies/systems used to provide energy services within the home (BRE 2007).
- Utley and Shorrock (2008) also highlight that there have been changes in the type and size of dwellings, with a growth in the number of detached houses and flats and a decrease in the numbers of terraced and semi-detached houses. The greater floor area of detached housing and their greater surface to volume ratio increase heat loss, compared to smaller buildings built with the same materials. However, the overall impact of these changes is difficult to quantify as higher energy use in larger buildings will be balanced by lower energy use in flats, etc.
- A further variable relating to housing is its location. This includes whether a house is in an urban or rural location, as this can influence the type of housing and the availability of gas (BRE 2007). It also includes the geographic location of a dwelling, for example because of different climatic conditions a house in Scotland in an average year is estimated to use nearly 45% more energy to maintain a given temperature than an identical house in the South West (Utley and Shorrock 2008).

3.1.2 Fabric insulation

On a GB basis, NS/DECC (2010) state that as well as higher energy efficiency levels in new build, the retrofitting of existing housing is playing a role in reducing energy losses, with average SAP ratings for the whole stock rising from around 15.5 in 1970 to 54.5 in 2008. This includes a range of different measures:

- Loft insulation – although it is estimated that around 95% of households had some loft insulation installed by 2007 (NS/DECC 2010), the latest estimates from DECC suggest that of the 23.3 million homes that have lofts, only 56% have insulation of at least 125mm installed (DECC 2011k).
- Cavity wall insulation – the latest figures suggest that of the 18.7 million homes that have cavity walls around 58% of have been insulated as of 2011 (DECC 2011k).
- Solid wall insulation – it is estimated that 7.9 million GB homes have solid walls and to date just over 1% have had insulation (installed via CERT and the previous energy efficiency commitments). In addition, it is estimated that around 900 000 homes have other forms of non-cavity wall insulation that fall outside the definition used for solid wall insulation (DECC 2011k[16]).
- Double glazing – it is estimated that around 85% of homes have double glazing in at least some, if not all, rooms (NS/DECC 2010), although the latest EHCS suggests that a high proportion could have full double glazing – 73% in England (NS/CLG 2011).
- Draught-proofing[17] – levels of this have also been increasing, partly as a result of the increased uptake of double glazing (Utley and Shorrock 2008).

3.1.3 Temperatures

Energy use for space heating is strongly correlated with season and external temperatures – for example, gas use is around five or six times higher in winter than summer (Owen & Ward 2010). Average external temperatures[18] have risen from around 5.8°C in 1970 to 6.4°C in 2008 (NS/DECC 2010). Patterns of internal temperature have also changed, increasing from an in-home average of 12°C in 1970 to 17.3°C in 2008, with NS/DECC (2010) suggesting that this relates to improved insulation, rising incomes and a growth in central heating use. However, it is also clear that there is a comfort element to the installation of central heating, not only in terms of the overall temperature, but also the number of rooms that are heated (Utley & Shorrock 2008).

3.1.4 Heating controls

Although not considered within the statistics, heating controls are also likely to play an important role in increasing the overall efficiency of heating systems, reducing the overall level of demand and emissions, whilst making bills more affordable. EST (2008) suggest up to 17% savings can be made through a full set of controls.

3.2 Trends in space heating

As discussed in section 2.1, space heating dominates final energy use in the domestic sector and most of this is provided by gas, with trends in total domestic gas consumption for space heating having increased by around 4059 ttoe between 1990 and 2008 (NS/DECC 2010), although consumption of gas for space heating peaked in 2004 and has since been in decline – Figure 5. In part it is assumed that the dominance of gas for space heating reflects the high availability of gas, with DECC (2010c) suggesting that in 2007, around 87% of homes in England had a gas connection. In Wales this figure is thought to be around 81% and connections in Scotland are thought to also be near to this level. The HHWT (2010) suggest the average figure is around 84% for the UK.

In looking at primary heating systems, BRE (2007) provide a detailed breakdown based on data in the EHCS, that shows that central heating, using a boiler system with radiators, is the dominant technology choice in England – Table 2.

Primary heating system	Percentage of total stock (%)
Boiler system with radiators	86.8
Storage radiators	7.0
Warm air systems	1.1
Room heater	3.3
Other systems	0.1
Communal	1.5
Portable heaters only	0.2

Table 2: Distribution of primary heating systems in England 2007. Source: BRE (2007:1)

[16] It should be noted that all the DECC data are released as Experimental Statistics while the methodology is developed and tested further, as such they are not yet classified as National Statistics (DECC 2011k:9).

[17] They define this as including single glazed windows that have draught stripes as well as double glazed windows (Utley & Shorrock 2008:27)

[18] Average external temperature during January to March, and October to December.

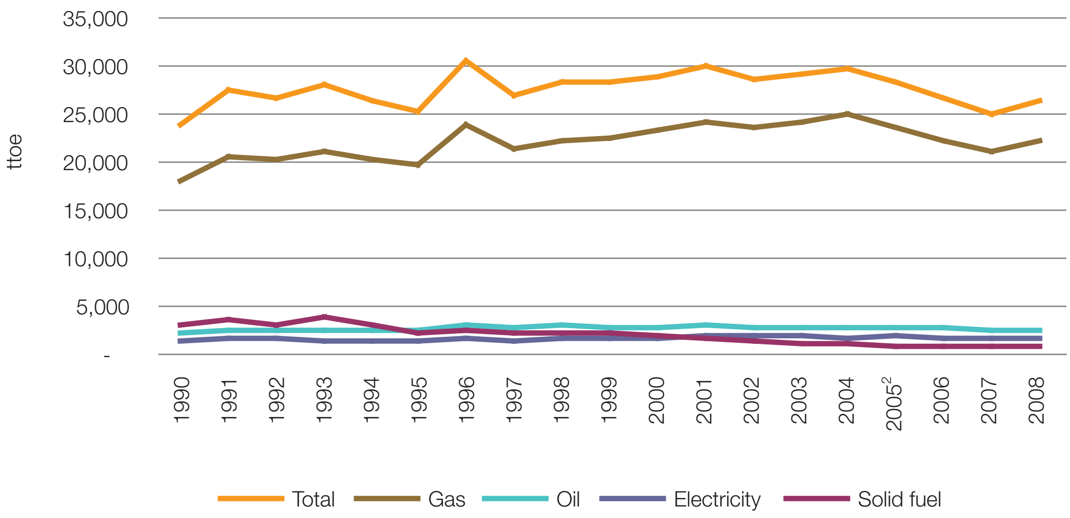

Figure 6: Trends in UK domestic energy use for space heating by fuel.
Source: NS/DECC (2010: Table 3.7)

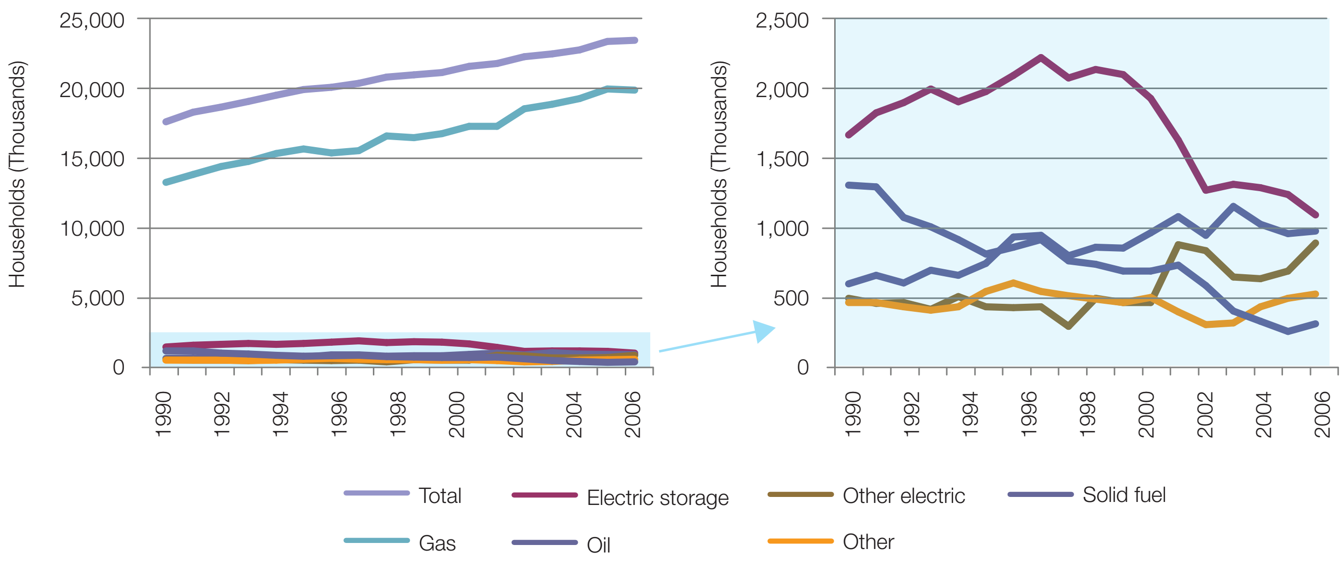

Figure 7: Ownership of central heating by fuel type in GB 1970 to 2007.
Source: NS/DECC (2010: Table 3.14)

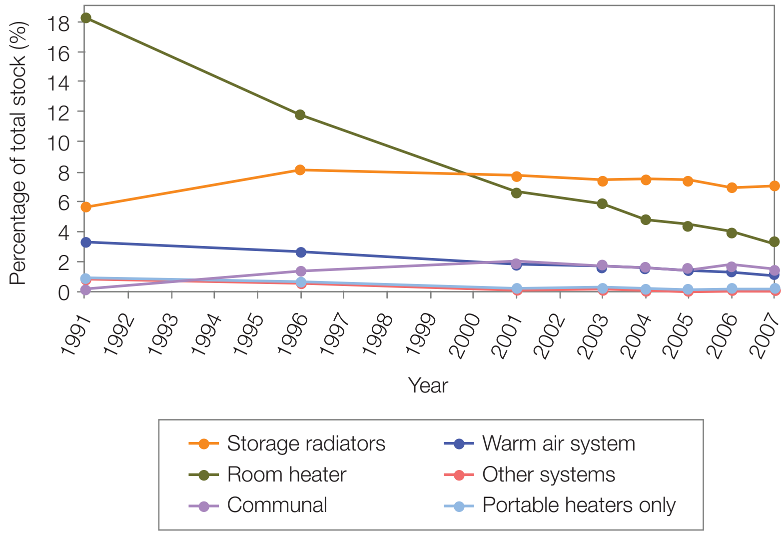

Figure 8: Timeline of other primary heating systems
Source: BRE (2007:2)

3.2.1 Central heating
Ownership of central heating systems in GB has increased from around 34% in the early 1970s to over 92% by 2007, around 23.5 million homes – Figure 6. The majority of these are gas fired systems, making up 85% of the market for central heating in 2007 using gas (NS/DECC 2010). Overall 78% of GB homes have gas central heating. The pop out shows the changing patterns of other forms of central heating; this suggests that solid fuel and electric storage heating have both been in decline, whilst there has been a steady growth in the use of oil, mainly within rural off-gas areas (BRE 2007), as well as a small growth in other forms of heat.

As of early 2009, the Heating and Hot Water Council suggest there were around 21.6m gas boilers in the UK, of which more than 6m were condensing boilers (27%). OFTEC also estimate that there are around 1.4 million oil fired boilers in UK homes, 7% of which are condensing (HHWT 2010). BRE highlight that the use of condensing boilers has increased dramatically, as they have been mandatory for new installations for energy efficiency reasons under Building Regulations since the mid 2000s, with condensing combination boilers proving to be the most popular (BRE 2007). It is suggested that around a third of GB homes had combination boilers installed by 2006 and that around 80% of all gas boiler sales are now for combination boilers (HHWT 2010).

3.2.2 Other heating
Leaving aside central heating, the trends in the other forms of primary heating within Table 3, since 1991, are shown in Figure 7. It can be seen that the use of off-peak storage heaters increased until around 1996, before declining; the use of fixed room heaters has declined rapidly; whilst there has been limited growth in communal heating systems. Other sources of primary heating have all declined since 1991 (BRE 2007).

It is worth noting that a number of homes also have secondary heating sources that act as a backup to the main heating. BRE (2007) suggest that around 70% of the stock in England has some form of secondary heating, mainly room heaters, particularly mains gas open or balanced flue heaters, but also including other forms of electric heaters and solid fuel fires.

3.3 Trends in hot water
Since 1990 the amount of energy used to heat hot water has steadily grown, increasing by 8% to 2008 (NS/DECC 2010). As with space heating the dominant fuel use for hot water is gas, which accounted for around 78% of the total demand in 2008 – Figure 8. This strongly links to the fact that the most common method of water heating is through the same system as space heating (BRE 2007) – Table 3.

Water heating system	Percentage of total stock (%)
With central heating	86.9
Dedicated boiler	1.2
Electric immersion heater	9.9
Instantaneous	2.0

Table 3: Distribution of water heating systems in England 2007. Source: BRE (2007:14)

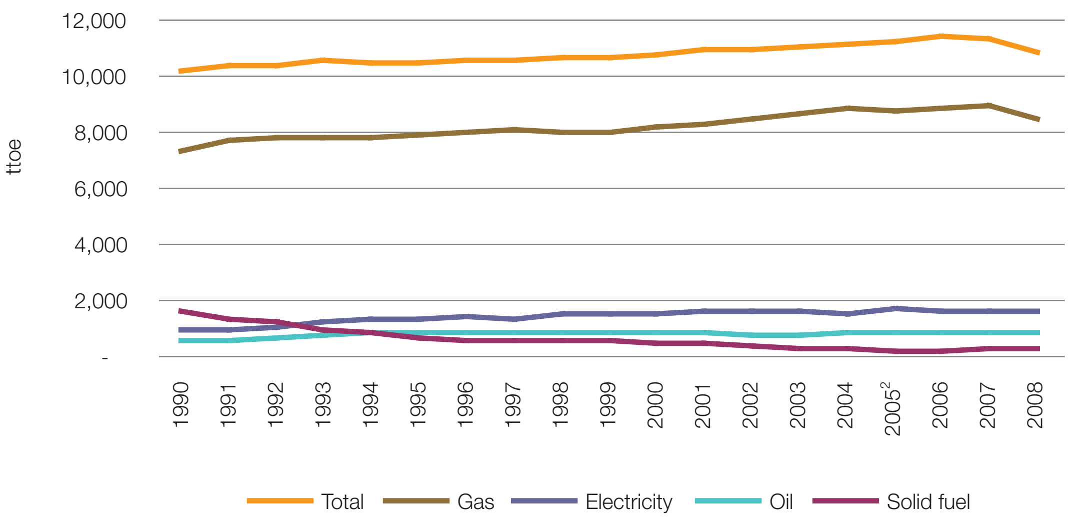

Figure 9: Trends in UK domestic energy use for hot water by fuel.
Source: NS/DECC (2010: Table 3.7)

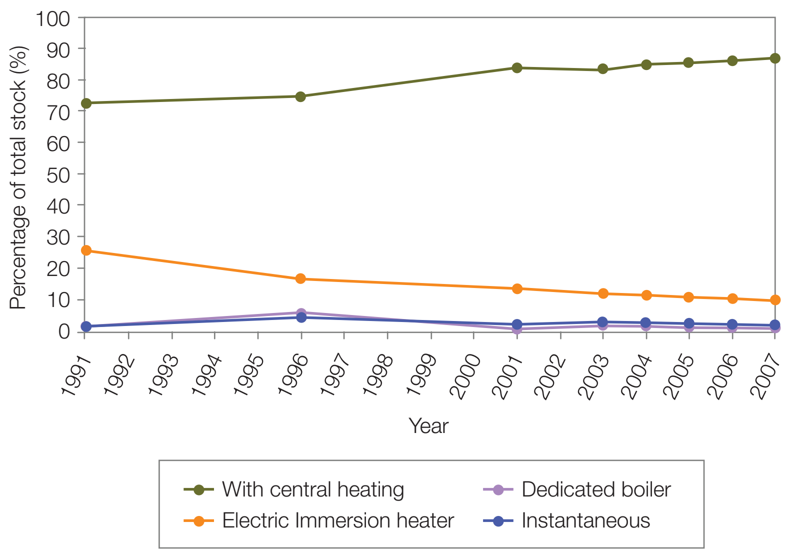

Figure 10: Timeline of water heating systems – England
Source: BRE (2007:14)

	1986	1991	1996	2001	2006	2008 (Est)
Number of GB homes	22.0m	23.2m	23.9m	24.8m	25.7m	26.1m
GB homes with a hot water tank	19.2m	20.2m	19.4m	18.4m	19.1m	19.1m
% of all GB homes	91%	90%	84%	77%	74%	73%
GB homes with combi-boiler	0.4m	1.3m	2.7m	5.2m	9.1m	11.0m
% of all GB homes	2%	6%	12%	22%	35%	42%

Table 4: Ownership of hot water tanks and combi-boilers GB.
Source: HWWT (2010:36)

Given that most hot water is provided via the central heating system, the growth in central heating is mirrored by a decline in other forms of hot water heating systems – Figure 9.

With respect to immersion heaters, it is estimated that nearly half the English stock has electric immersion heaters, but these are not included in the analysis above, as they are not the primary source of providing hot water. Instead they play a back-up role or are used for meeting high household demand (BRE 2007). Probably just over 10% of households heat their hot-water with electricity – other than instantaneous electric showers, a large proportion of that is likely to be off-peak. The growth in the use of combination boilers has also seen the level of ownership for hot water tanks reduce. In terms of the total stock it is estimated that around 73% now has a hot water tank, compared to around 91% in 1986 – Table 4 (HHWT 2010).

3.4 Trends in cooking

The final energy demand for cooking (hobs and ovens) has declined since the 1990s by around 14%, standing at 1,300 ttoe in 2008. This is almost equally split between gas and electricity which dominate the fuels used for cooking[19] – Figure 10 (NS/DECC 2010). However, it is apparent that there are differences in fuel choices for ovens and hobs; Defra (2009) suggest that in 2009 approximately 64% of ovens were electric and 35% were gas, and for hobs the split was 45% electric and 55% gas.

[19] The apparent jump in electricity use for cooking between 2005 and 2006, reflects statistical revisions to the way electricity consumption is calculated with DUKES back to 2005 (Communication with DECC June 2011).

4. Factors Influencing Choices in Technologies and Fuels

The previous section clearly shows the dominance of gas within existing homes, particularly for space and water heating. Within this section, we consider what factors may be influencing the choice of technologies and fuels and how satisfied people are with them; before considering a wide range other issues that could influence preferences including inertia, the opportunities for intervention and attitudes and behaviour.

There is surprisingly little recent published research into the choices that consumers make with respect to technology or fuels, although there is a range of factors that can influence this, relating to buildings characteristics, tenure, etc. There are also some data which consider consumer satisfaction with different technologies for space, water heating and cooking. Along with energy trends discussed above, these provide an indication of possible underlying preferences, but detailed evidence into why UK consumers choose a particular technology or fuel is not available.

4.1 Space heating

4.1.1 Housing factors

There is a range of underlying physical and social factors likely to influence the sort of technologies and fuels used to provide space heating, with many links between the two. Most of the data comes from the EHCS and was produced by BRE (2007). In looking at technologies they suggest the following factors can have an impact on what is used:

- Dwelling Type – houses are much more likely to have central heating than flats, with flats tending to have a larger proportion of storage radiators or a communal heating system. This links to a more general correlation between total floor area and the type of heating systems, with the sorts of primary heating system used increasing in diversity within smaller properties. The size of a dwelling can also see a preference towards combination boilers in smaller dwellings, as they save space as neither a water tank or hot water cylinder need to be fitted;
- Dwelling Age – central heating is the most

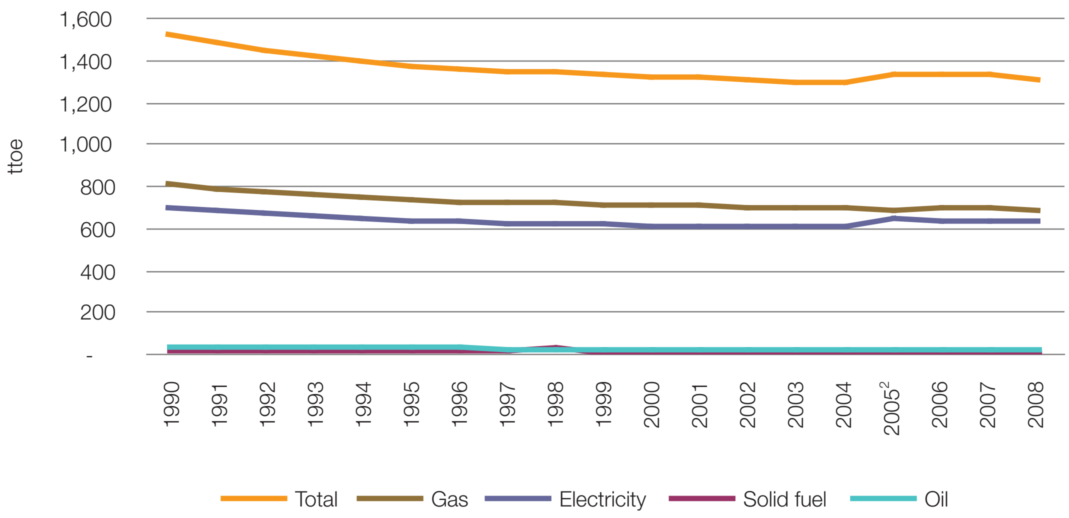

Figure 11: Trends in UK domestic energy use for cooking by fuel (hob and ovens). Source: NS/DECC (2010: Table 3.7)

common form of heating in all ages of properties, but alternative primary heating sources are more common in houses built between 1965 and 1980;
- Tenure – the highest proportion of central heating is found in the owner occupier sector;
- Household Type – single person households and lower income households are less likely to have central heating systems;
- Location – around a third of homes in rural areas are off-gas and therefore have a higher proportion of alternative heating system in use, as well as making more use of secondary heating sources.

In looking at fuel use, many of the factors above also influence what is used, with particularly strong links between dwelling size and location, and fuel type. BRE (2007) highlight the following factors that link to the type of fuel used:

- Gas – the most common heating fuel for all dwelling types and tenure groups, although its use does change with many of the factors highlighted above. Of these, access to gas is clearly the main factor and this leads to some regional variations as some areas have a higher proportion of rural dwellings, including the South East, East of England and South West;
- Electricity – more commonly used in properties with smaller floor areas, with flats in particular having a higher proportion of electrical systems (mostly likely modern flats). High urban density, where flats are more common, can therefore increase the likelihood of electricity use. Electric heating is also more prevalent in the private rented and social housing sectors than the owner occupier sector. It is also more commonly found in single person households;
- Oil – tends to be used in older and larger properties, in part reflecting that many of these are found within rural areas that are off-gas. There are also some links to income, with higher income groups tending to have oil fired central heating, but again this relates at least in part to location, as there is a high proportion of high income groups living in rural housing;
- Solid Fuels – solid fuel systems also tend to be found in older properties (pre-1919) and in rural areas, although it does not tend to be used in particularly large or small dwellings. There are also apparent historic/cultural links to coal use, with around a fifth of dwellings using solid fuels found in Yorkshire and Humberside. Its use also tends to be more prevalent in lower income households.

4.1.2 Satisfaction

BRE (2007) also provide a summary of household satisfaction for primary heating systems in England – Figure 11. It suggests that the highest levels of satisfaction are for central heating systems, with 93% of households rating these as being either very or fairly effective; there is also high satisfaction with communal heating. Lower levels of satisfaction are shown for storage heaters, warm air systems, room heaters and other systems. Portable room heaters appear to score the lowest in terms of user satisfaction.

There is also information available on the satisfaction rating of different types of boilers – Figure 12 (BRE 2007). This shows a high level of satisfaction with all types of condensing boilers, with 76% of households finding them very effective. There is less satisfaction with systems that use back boilers and standard boilers, and those houses with no boilers also indicate lower levels of satisfaction with alternative heating systems.

The feedback in the ECHS also mirrors findings from focus group work with owner-occupiers and renters that have shown that householders are largely satisfied with their current heating systems, particularly so for gas central heating, whilst non-gas users were found to be more dissatisfied, especially with the running costs. Specific minor dislikes included: insufficient hot water for users of LPG and electric heating; difficulty in operating electric (presumably Economy 7) and coal fired systems; unreliability/high maintenance for users of wood, oil and coal-fired systems; and some electric heating systems producing heat at the wrong time of day (Element Energy 2008).

4.1.3 Choice

Unpicking all of the interrelated factors that can influence the type of technology and fuel used and considering people satisfaction provides some indication of choice, although many of the links are inferred.

With respect to technology there is a clear expectation of central heating, reflecting the high levels of satisfaction that are shown for this form of primary space heating and apparent by the growth that has occurred in the number of installations since the 1970s. BRE suggest that "the perceived effectiveness of this type of system has probably been a factor in the increasing proportions of this type of heating system, as new or replacement heating systems are installed" BRE (2007:2). Choice of technology is also likely to be determined by a range of housing-related factors, including tenure, with those in rented accommodation not necessarily having a choice of the type of system that they can use for heat, whereas owner occupiers may to a greater degree decide on the system they want and they appear to favour the installation of central heating, with BRE (2007) suggesting that the perceived effectiveness of central heating explains

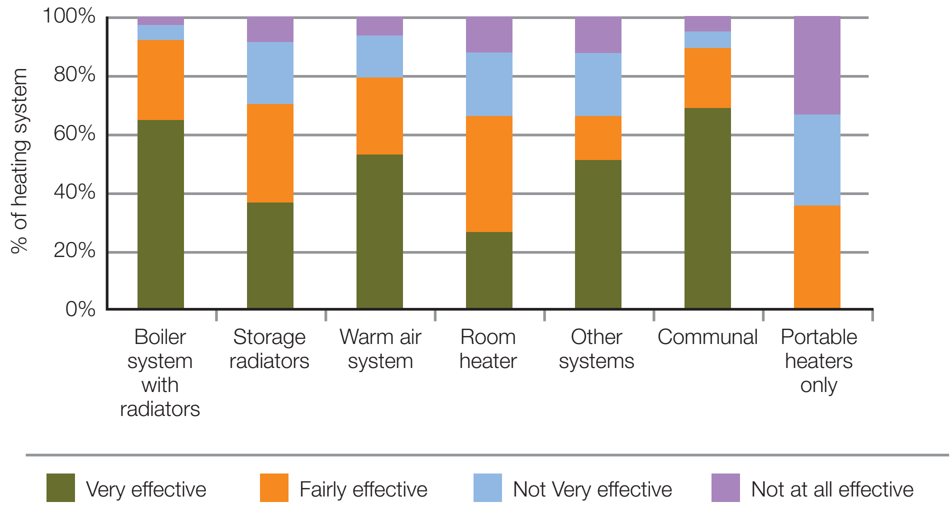

Figure 12: Comparison of space heating systems by household satisfaction rating, England. Source: BRE (2007:2)

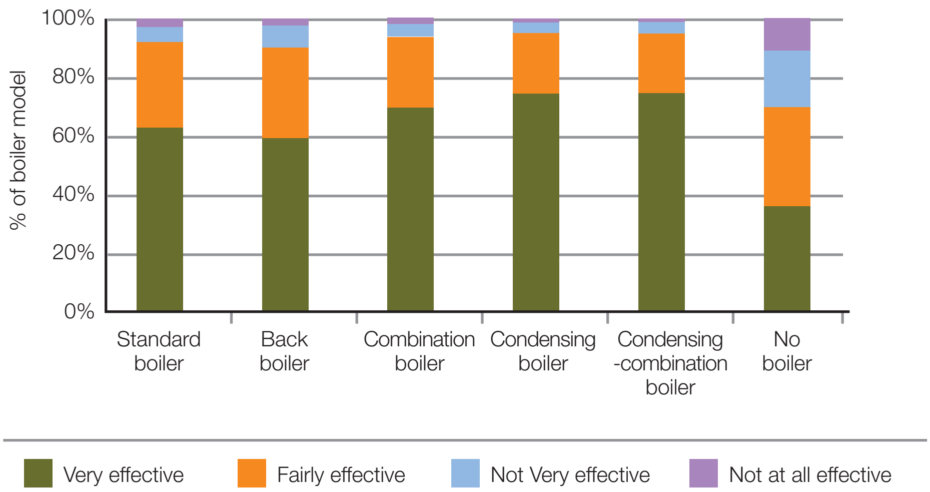

Figure 13: Satisfaction ratings for boilers in England
Source: BRE (2007:9)

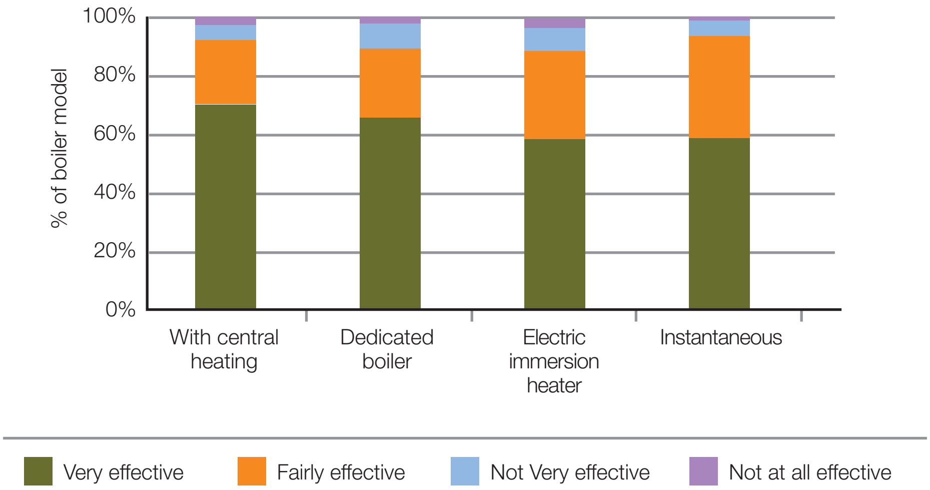

Figure 14: Comparison of water heating system by household rating in England. Source: BRE (2007:14)

why this tenure has the highest proportion of central heating. Lower levels of satisfaction are also evident for other forms of primary heating systems.

In terms of fuel choice, again the BRE data clearly show that a wide range of factors relating to the characteristics of the dwelling and the type of tenure/household will have an influence on the type of fuel that is used, with locational factors, such as housing density and rurality, having a particularly strong influence. Data from previous sections show the dominance of gas in providing space heating in the UK and the level of growth in gas use since the 1970s suggests that this has been the main fuel of choice to provide space heating, given that other than oil, the use of other fuel types has declined. This could be influenced by a range of further factors, such as the high availability of gas and technical and efficiency advances in boilers and central heating systems as well as evidence and advice from organisations such as EST that shows the relative cost advantage of using gas compared to other fuels to provide space heating (EST 2006).

A further factor that could influence technology and fuel is the growing expectation for thermal comfort, reflected by both the increase in average internal temperatures and the shift towards heating the whole house, rather than single rooms. It has been shown in several studies that comfort is a key consideration for domestic heating (Whitmarsh et al 2011) and calls to energy advice centres also show that comfort is one of the reasons that people seek advice (EST 2010). Data from the EHCS also show that comfort and facilities rate highly with respect to how people view their homes (NHBC 2007). Systems that can easily and cost effectively enable this are likely to be favoured.

4.2 Water heating

4.2.1 Housing factors

Given the strong links between space and hot water heating systems, the housing factors highlighted above and in section 4.1.1, will also influence the technologies and fuels used to provide hot water. For example, flats, which have the lowest levels of central heating, have a higher proportion of different hot water heating technologies and fuels, etc. (BRE 2007). The growth in the use of combination boilers (mainly but not exclusively gas) has also changed the nature of hot water systems within dwellings, evident from the falling numbers of homes with hot water tanks (Table 4) and therefore the number of electric immersion heaters in use.

4.2.2 Satisfaction

There are generally high levels of satisfaction with the systems used for heating water, with BRE (2007) suggesting that at least 89% of households rate their system as being very or fairly effective. The highest levels of satisfaction are shown by those with water heating that is linked to central heating, with 94% rating it as effective. The lowest levels of satisfaction are shown by those using immersion heaters, with 11% finding the system not very or not at all effective.

4.2.3 Choice

Unpicking choice for how hot water is provided is difficult. It is clear that preference and satisfaction appear to favour those systems that are linked to central heating, so many of the points above apply equally to hot water. However, there is a clear trend towards the installation of combination boilers, with a suggestion that these now account for around 80% of gas boiler sales (HHWT 2010). BRE (2007) suggest that the ease of their installation and the space saving that they offer are factors behind this, although it is also clear that many homes do have a split system of using both combi-boilers and a hot water storage system (HHWT 2010).

4.3 Cooking

Unlike space and water heating, there is little discussion on the links between cooking in terms of housing factors and satisfaction. However, there are data and discussion that reflect preferences for different cooking methods. Compared to other energy services within the home, energy use for cooking has been declining and this has happened at the same time that housing and population numbers have increased. It could be speculated that this reflects changes in eating habits, such as a growing demand in convenience foods, as well as changes in cooking habits, e.g. more microwave cooking. Examining electricity use for cooking shows that demand has particularly increased for the use of electric kettles and microwaves – Figure 14. There has also been a corresponding growth in microwave ownership, increasing from around 60% of households in the early 1990s to 92% by 2009 (NS/DECC 2010).

Looking at the fuels that are used for ovens, Defra (2009) suggest that consumers increasingly prefer to buy electric rather than gas ovens because they are believed to cook more evenly. They suggest that electric ovens currently make up 64% of the stock and they anticipate that this will increase to around 70% by 2020, with a proportional decrease in gas ovens. Advice from consumer organisations such as Which? also highlighted the perceived effectiveness of electric oven gas, even though they cost more to run (Which? 2011b) – suggesting an active choice by consumers. Which? also suggest that the preference towards electric may also reflect their more multifunctional nature, although they suggest that previous experience also impacts on preferences for cooking technology.

For hobs, the opposite appears to be reflected in consumer choice. Defra (2009) suggest that currently the split between gas and electric hobs is 55%:45% respectively and they think this may increase to around 60:40 by 2020. Defra suggest that consumers prefer gas because of the flexible control of temperature it offers and even with developments in electric hobs they doubt that these preferences will change. Which? (2011b) also highlight the instantaneous nature of gas hobs in their guidance to consumers. There was also a long marketing campaign by British Gas that started in 1978 and ran through the 1980s promoting the 'cookability' of gas, which may have influenced underlying perceptions, at least in terms of gas hobs.

4.4 Wider factors influencing choice

Whilst all of the above information gives some indications of how consumers currently view and use different technologies and fuels, there is a very limited amount of work that has specifically examined underlying preferences in this area[20], making generalised assumptions on what is driving choice and how to influence it is therefore difficult. However, there is a much wider range of issues that add further depth and understanding, which are examined below.

4.4.1 Fuel and technology costs

Surveys with consumers on the aspects of their home that they rate as important have shown that running costs get the highest rating (NHBC 2009). In addition, a recent survey by Which? (Which 2011a) showed that rising energy costs were the biggest economic concerns for consumers currently. This suggests that comparative running costs for the provision of heat will play an important factor in influencing choice over the type of technologies and fuels that may be used. In the case of gas heating, it has been shown that running costs, compared to other fuels, are lower (EST 2006; CFW 2010) and upfront capital costs are also typically lower, with replacement boiler costs estimated at £2,500 (assuming no changes to wet-radiator system) (EST 2011a), although average costs for just a boiler could be nearer £2,000 based on the boiler scrappage scheme (EST/TNS 2011).

In comparing gas boilers with a range of renewable heat technologies, modelling for the CCC from EE/NERA (2011) uses a levelised cost of energy (LCOE) which shows the relative cost penalty for alternatives to gas heating, giving an indication of the level of support that would be required under the RHI to help overcome financial barriers – Table 5 (CCC 2011). Future changes between the relative cost of gas to electricity and other fuels will influence the relationships between different technologies.

4.4.2 Inertia

Notwithstanding consumer concerns about the impact of high energy prices on household budgets, as the satisfaction surveys above demonstrate, consumers appear generally content with the way that they currently meet their energy needs, particularly in the case of space and water heating using gas. Other surveys have also highlighted that most do not have any significant dislikes in relation to their current heating system and that their replacement is a low priority decision, which consumers are unlikely to devote much attention to (Element Energy 2008). This is likely to be particularly true for on-gas households, given that gas dominates the domestic heat market and uses technologies with an established reputation for reliability and consumer familiarity as well as having access to reliable fuel supply via the gas grid (EE/NERA 2011).

	Technology	Property Type			Estimated Cost vs gas p/kWh
		Suburban New Build	Suburban Other	Suburban Solid Wall Insulation	
LCOE (p/kWh)	Gas boiler	10.5	7.7	6.8	0
	ASHP	16.5	12.6	10.9	4 – 6
	GSHP	18.6	17.2	12.8	6 – 9.5
	Biomass boiler	23.7	18.3	15.3	9 –13
	Solar thermal	26.6	26.6	26.6	16 – 20

Costs are for current installations, based on 2011 cost data and capital costs are annualised over a 15-year period at an interest rate of 8%.

Table 5: Levelised cost comparisons and estimates of cost penalties for renewable heat, by housing type. Source: After CCC (2011: 133)

[20] This is based on both reviews of the literature as well as conversations with academics and a range of different organisations (CCC, DECC, CLG, BRE, EST, Element Energy, HETAS, BEAMA and IDHEE).

In looking at the possible reasons why householders would consider changing energy systems, Element Energy (2008) suggested they include breakdown, insufficient capacity, unreliability, and hassle factors, such as manual operations including needing to clean and maintain the system, and difficulties in obtaining parts. The main barriers to change were cited as cost, hassle, inertia and a lack of interest or knowledge in what else there is and what benefits could be gained. It is also evident that many boiler replacements are distress purchases, basically replacing like for like (but condensing) (HHWT 2010) with little time given to considering alternative forms of heating. There is also evidence to show that consumers are willing and able to repair older boilers, rather than investing in new ones (HHWT 2010). The work done by Element Energy (2008) suggests that factors influencing the choice of any new system include capital and running costs, with people wanting to spend no more than was essential to get a system that meets all their key needs; whilst the idea of reducing operating costs was also attractive to most. Reliability was also a key issue and this was generally seen as a component of the operating costs. Most importantly it was seen as essential that a system could meet all the household's needs, without capacity limitations, with a preference shown for having all in one systems (e.g. combi-boilers) that could supply all heating and hot water on demand, as opposed to having multiple appliances/systems. Boilers also have a relatively long life, meaning that once installed they may not be replaced for 15 years. And if the existing radiators do not need changing, then the most disruptive element of any change – and probably the most expensive element of the heating system – is already installed.

The combined effect of all these factors suggests there will be a high level of inertia in the domestic heating market, although in many respects this appears to be more of an effective 'default' to gas which manifests itself as seeming inertia (in on-gas households). For renewable heat to penetrate the on-gas market, mainly post-2030, these issues will need to be overcome.

4.4.3 Intervention points

One potential way to address the 'default to gas' is to work with natural intervention or trigger points, which can also strongly link to attitudes and behaviour (4.5.3). There has been a range of work looking at how to encourage the uptake of measures, particularly for energy efficiency. Recent work by EST (2011b) highlights that the best time to undertake significant improvements to the efficiency of a home is when other work is already planned or under way either inside or outside the home, as this can reduce hassle, disruption and costs. The HHWT (2010) also highlighted the opportunities to make improvements to existing homes as part of their renovation, repair and maintenance. EST (2011b) suggest that this could include work such as fitting new kitchens, bathrooms or building extensions, although they suggest the most common refurbishment projects are single-room redecorations and refitting.

Based on their survey work EST (2011b) suggest that around 3.9 million homeowners are planning or anticipating a major refurbishment project within three years and in most cases are willing to stretch refurbishment budgets to incorporate energy efficiency measures. The HHWT (2010) also highlight the large numbers of small planning applications that are made to UK councils every year and suggest that ONS statistics show that repair and maintenance activity accounts for 45% of all work in the construction industry. Based on this data it is apparent that there could be a large opportunity for retrofitting low carbon measures into existing homes during their renovation, although the actual scale of this is difficult to accurately estimate (HHWT 2010).

The other potentially significant trigger point for home improvements is through house purchases, when it is suggested that people are more amenable to fitting energy-efficient products and/or adopting new environmentally friendly habits, with the Government currently changing the information on EPCs to better convey information to those individuals that are best placed to take action (CO 2011). The number of property transactions, prior to the recession, was running at more than 1.5 million a year, with more recent data suggesting this has fallen to around 0.8m to 0.9m a year (ONS/CML in HHWT 2010). The level of opportunity in terms of the amount of renovation work that is going on is again difficult to estimate. It is known that owner occupiers are willing to invest in improvements, such as energy efficiency, within their homes (BRE 2007; EST 2011b), but it is also apparent that average tenure for owner-occupiers is seven years, which reduces the willingness to invest unless there is a quick payback (EE/NERA 2011). In the private rented sector research highlights that private landlords plan bigger refurbishment projects and spend more on each project than homeowners, but landlords can be more sceptical about energy efficiency improvements than owner-occupiers, even if they see the logic of fitting them as part of a refurbishment project (EST 2011b). There is also a well documented institutional barrier with respect to the landlord-tenant split, where the cost to the landlord for measures may not be recouped through higher rents (EE/NERA 2011).

In relation to heating, there is evidence to suggest that consumers want to install something that is tried and tested, with concerns over the perceived risk of installing something unconventional. For owner occupiers this can include a concern that such a system could deter potential buyers when they come to sell, potentially reducing the value of the property (EE/NERA 2011) – something that may also concern landlords and their ability to rent a property. However, there is limited evidence about attitudes in these respects (EE/NERA 2011).

4.4.4 Attitudes and behaviour

A much wider body of work, which will have links to understanding people's preferences, relates to attitude and behavioural studies, which have included research into people's views towards different technologies. Understanding attitude and behaviour and how to influence them is likely to play an increasingly important role in moving towards a low carbon economy as it is not just about the technologies that are available, but people's role and interaction with them, in terms of take-up and their effective ongoing use.

A recent large scale review of the literature shows that energy use is driven by a range of issues, which include many of the points above relating to structural issues (such as location, tenure type, household size, etc) along with economic factors (income, cost, etc), social factors (status, meaning, identity, etc) and by everyday consumption practices and habit, with environmental values tending to have relatively little influence (Whitmarsh et al 2011). The review also highlights the importance of public perceptions towards energy, given the need for new infrastructure and technologies, as well as changes to current patterns of demand in transition to low carbon.

Attitudes and behaviour theory

In their first report the CCC highlight Defra's work on pro-environmental behaviours that examined attitudes and beliefs towards the environment to identify those that are willing and able to do more, and those less able or willing to act (Defra 2008 in CCC 2008). The CCC suggest this work shows the considerable challenges in reducing emissions, but highlight that appropriate policies can help with the uptake of measures, particularly where disruption and lifestyle change are least (e.g. cavity wall insulation, loft insulation and the purchase of more efficient appliances and lights). Persuading people to undertake more disruptive measures such as solid wall insulation (or low carbon heat) is likely to require a greater degree of subsidy, encouragement or compulsion (CCC 2008).

The work by Whitmarsh et al (2011) provides a detailed review on theory around attitudinal and engagement processes and practice. It describes how from a psychology perspective attitudes can be seen as hypothetical constructs that refer to an individual's evaluation of something, having three main dimensions – knowledge (intellect and cognition), affect (emotion and feeling) and behavioural intentions. Attitudes can be changed and influenced by a range of factors, such as persuasion, experience and as a result of behaviour change itself. With respect to low carbon energy, they suggest public attitudes and responses are dynamic and complex, being determined by a range of interactions between psychological, social and structural factors. Furthermore, attitudes are not necessarily predictive of behaviour, but do fulfil important functions, such as informing decisions, even if they do not determine behaviour. They also describe a 'practices' approach to behaviour change that places less emphasis on attitudes, instead seeing habits and routines as more important in explaining behaviour. With this approach the main route to changing behaviour is seen to come from changing the social, economic, political and technological context of an individual's daily life.

A recent report from the Cabinet Office (CO 2011) into behaviour change and energy use considers some of the underlying issues for encouraging the uptake of energy efficiency measures. It draws on insights from behavioural economics and psychology to consider how people behave and use energy, and why they do not currently act, in order to consider ways to facilitate people to become more energy efficient. It highlights how people deviate from rational choice models (citing Wilson & Dowlatabadi 2007 and Jackson 2005) and how stated preferences, such as concern about the environment, do not translate into action, i.e. revealed preferences (Kollmuss and Agyeman 2002 in CO 2011). It then considers the role that social, cognitive and behavioural factors play in explaining this, and suggests three significant insights including:

- tendency to discount the future – in which people appear to prefer smaller rewards today, rather than larger rewards in the future, which can impact on the uptake of measures in which the benefits are accrued over a long period of time, like energy efficiency (and arguably more so for low carbon heat);
- power of social norms – which shows how people are heavily influenced by what others around them are doing;
- use of defaults – which shows how people can tend to go with the flow of pre-set options, or defaults, often regardless of whether these options maximise individual or collective wellbeing (CO 2011:6/7).

Attitudes and behaviour studies

The review by Whitmarsh et al (2009) considered a range of specific studies, highlighting a tendency to focus on individual technologies or developments, rather than attitudes to policy, energy systems or scenarios. However, they do highlight three higher level studies in this area:

- The Big Energy Shift – which worked with 30 households in 2009 to consider people's views of the energy system. It found that people were supportive of changes in energy supply and consumption providing that their quality of life remained the same and they are helped to change. This included well-designed and affordable packages of support for microgeneration and energy efficiency, supported by a strong and sustained message from Government, which should also lead by example. The study also suggested that people felt change should eventually be backed with penalties for non-compliance (Ipsos-MORI 2009 in Whitmarsh et al 2011)
- A forthcoming study that worked with 40 members of the public in Manchester to examine heat and power in the domestic sector in relation to emission reduction targets of 42% by 2020 and 90% by 2050. The study included ranking different options to cut emissions in homes, suggesting that energy efficiency was generally ranked first followed by a range of microgeneration options. It highlighted gaps in understanding for some technologies and a view that retrofitting was seen as more problematic than new build. The participants felt the 42% emission reduction target could be achieved through reduced energy consumption, changes to the mix of electricity generation and microgeneration (heat and power). The 90% emission reduction was found to be more difficult because it would require zero emissions from gas which would require more substantial change. It was also suggested that Government intervention would be critical, but overtones of compulsions should be avoided (Carney & Upham forthcoming in Whitmarsh et al 2011:126/7).
- A forthcoming UKERC funded project that Cardiff University are leading that will investigate public perceptions of whole energy system transformation.

The review by Whitmarsh et al (2011) also summarises the findings of a number of studies linked to energy efficiency. It highlights that people perceive energy efficiency measures and energy conservation as separate categories of 'behaviour'; and whilst it is suggested that a majority of people consider reducing household energy use as a virtuous thing to do, policies to reduce energy use are suggested as being generally unpopular, as is enthusiasm for changing lifestyles. A number of area specific findings in the Whitmarsh study include:

- a British survey by Spence et al (2010) that found that although people tend to agree that they are prepared to do things to reduce energy use, few are willing to spend significantly more money for energy efficient products;
- research from Defra (2009) that shows that attitudes to insulation are positive and from EST (2010b) that suggests people see energy efficient homes as having more value;
- evidence of the barriers faced in the private rented sector for installing insulation, linked to landlords' willingness to invest;
- a general lack of understanding over what is possible and difficulties in understanding the issues;
- an apparent growing stated willingness to change energy habits with actions to save electricity for lighting being more popular than heat and washing related activities (EST 2010).

The Whitmarsh et al (2011) review also highlights a range of studies that have examined the reasons why people adopt, or fail to adopt, microgeneration. Many of these are discussed in detail in section 5, but headline findings that link to renewable heat suggest that positive motivations for installation include perceptions of low running costs, self-sufficiency, ready access to raw materials and positive environmental performance. A number of common barriers were also found across a range of different studies, such as:

- high upfront capital costs and long payback periods;
- lack of awareness or understanding of different options;
- uncertainty around efficiency, effectiveness, consistency and environmental performance;
- finding credible installers and suppliers;
- hassle factors associated with having work done, or for ongoing operation (biomass);
- concerns about ease and costs of maintenance;
- the inability of renewable technologies to satisfy all heat requirements (Whitmarsh et al 2011).

The Government is currently in the process of running a series of field trials based on their behavioural evidence linking to the development of the Green Deal and RHI (CO 2011). With respect to energy efficiency and the Green Deal the trials will test the effectiveness of upfront incentives in encouraging uptake for individuals and groups and ways to reduce hassle factors for loft insulation. For renewable heat, the Premium Payments for households in 2011 will be used to monitor and understand how people use equipment once it is installed. The government also highlight that they will consider how behaviour insights should influence the design of policy in respect to segmentation, discount rate, non-financial barriers, private utility and inertia. It is also apparent that DECC are building the internal capacity to work on behavioural aspects of their programmes[21].

[21] Personal communication with DECC June 2011.

5. Future Options for Dealing with Direct Emissions from Fossil Fuels within the Domestic Sector

This section considers some of the mechanisms that are available for reducing the direct emissions associated with the use of heat in existing housing, and sets out the context for future choices. Improving energy efficiency will be central to this, but increasingly renewable heat uptake will be important. Consideration is given to the different options that are projected to play a role, including insight into consumer satisfaction with them and some of the existing issues and barriers to takeup. However, given that up to 2030 much of the projected uptake of renewable heat could occur in new build and well insulated off-gas housing, the need to increase efficiency in on-gas housing before this period will play an important role in decarbonising heat and increasing affordability and comfort. The final part of this section considers some of the current and future options for increasing gas efficiency. Much of this section draws on the modelling carried out for the CCC by Element Energy and NERA and the CCC's interpretations of it, as this provides a recent and comprehensive overview of many of the key issues.

5.1 Renewable heat options

Options for renewable heat within the domestic sector differ in lots of respects from some other forms of microgeneration, such as PV, which can have a fit-and-forget attitude, whereas heating systems are integral to people's lives, are used on a daily basis and are fundamental to comfort (EE/NERA 2011). It is suggested that, based on the evidence from both social research and modelling, the large scale uptake of renewable heat technologies will be challenging before 2020 (Weiner 2009), and much of the early focus, including the RHI, may be directed towards off-gas grid housing (DECC 2011f) where the price of the incumbent

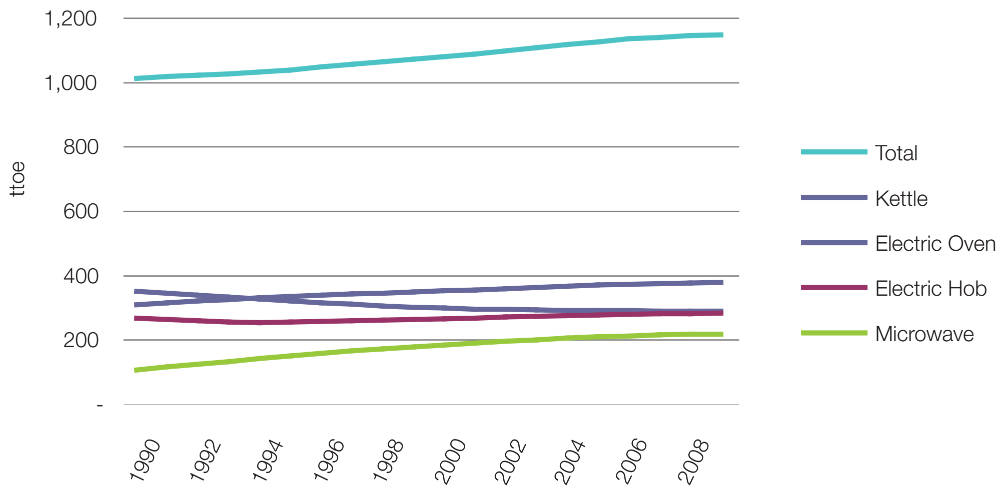

Figure 15: Electricity use for 'cooking' (DECC modelling)
Source: NS/DECC (2010: table 3.10)

fuel (i.e. oil) is higher than gas (EE/NERA 2011; EST 2011a), or a wish to increase comfort (i.e. Economy 7). However, in the longer term it is also recognised that to reach the carbon budgets it will also be necessary to get takeup in on-gas households (EE/NERA 2011). Based on the possible number of new builds (section 2.2) and CCC's projections (CCC 2010) this becomes particularly important post-2030.

There is a range of technologies that can provide low carbon space and water within the domestic sector. Based on the various models that have been carried out for DECC and the CCC, the options are expected to mostly come forward in the domestic sector to the 2020s and 2030s and include ASHPs (mainly air to water), GSHPs, biomass boilers and solar thermal, along with increasing use of biogas. To a lesser extent there could also be a role for district heating and other forms of heat pumps – Figure 15.

5.1.1 Heat pumps

Heat pumps operate most efficiently with low temperature heat distribution systems such as underfloor heating or low temperature radiators, which suggest they are likely to be most suitable for new build housing or in existing homes with high levels of thermal insulation (CCC 2011; EE/NERA 2011). Subject to good energy efficiency, EST (2011a) suggests that these may be most suitable initially for those that are off the gas network. The CCC suggests that heat pumps could be installed in around 0.6 million homes by 2020, rising to 6.2 million homes in the 2030s (CCC 2010): it seems likely that most of these could be within new build and off-gas housing, whilst the higher penetration rates of between 55% and 75% of homes by 2050 suggested by CCC (2010) will require takeup increasingly in the on-gas housing sector from the 2030s. Analysis by AEA for DECC suggests that there are currently around 28,000 heat pumps installed in the domestic sector, mainly within new build (DECC 2011i) and it is likely that the vast majority of installations to date are GSHPs (HHWT 2010).

Of the different types of heat pumps, most modelling considers that the use of ASHPs and GSHPs will be most applicable within the domestic sector. Information on installation costs from EST (2011a) suggests that ASHPs cost £6,000 to £10,000 and GSHPs cost £9,000 to £17,000 (excluding costs for heat distribution if this is also installed) and they have projected annual running costs of around £650 to £750 per year, with the potential for lower running costs compared with oil, direct electric, LPG, or coal. The capital cost for installations is projected to fall by around 30% by 2030 (NERA/AEA 2008 in CCC 2010), although running costs are expected to rise with increasing electricity prices (DECC 2011i).

5.1.2 Biomass heating

Takeup of biomass boilers is projected to be low by the CCC (2010) at less than 0.1 million installations by 2020 rising to 0.9 million by 2030, reflecting issues over sustainable sourcing of fuels, air quality and the possibility that the best use of the resource will be in other sectors.

Current estimates on the use of biomass are difficult to obtain, although recent data in Energy Trends, suggest that around 1,212 ktoe of renewable heat was produced in 2010 and around 391 ktoe of this was from the combustion of wood within the domestic sector (NS/DECC 2011b).

EST (2011a) suggests that biomass heating will be most suitable for homes off the gas network, assuming that there is sufficient space for equipment and fuel storage. Technologies include boilers and room stoves that can use pellets or logs. Typical installed costs are around £3,000 for a stove and £11,500 for a complete domestic pellet boiler system. Ongoing running costs are sensitive to the price of biomass and EST suggests that costs are currently comparable with coal and less expensive than LPG and electric heating.

5.1.3 Solar thermal

The CCC (2010) also see a limited role for solar thermal in contributing to the carbon budgets, mainly because of its high cost, with the baseline modelling by EE/NERA (2011) suggesting that cumulative sales could be around 22,000 units per annum by 2020.

Unlike the other technologies above, solar thermal is not a direct replacement for heating systems, instead being used to provide a proportion of a building's hot water demand (EE/NERA 2011). EST (2011a) suggest that it can generally be integrated into existing hot water systems, although it does not work with some combi-boilers and it requires a large hot water tank which can create space issues in some dwellings. Typical installation costs are estimated at £4,000 to £6,000 (EST 2011a).

A review in 2008 suggested that as of that year there were around 90,000 solar thermal installations, accounting for around 90% of all microgeneration measures (Element Energy 2008 in HHWT 2010). The same report suggested that sales figures averaged around 6,000 units a year, although other estimates have suggested it could be almost double this (HHWT 2010). Although CCC (2011) suggest that takeup will be low, EE/NERA (2011) highlight that this may not be the reality, given that of all forms of renewable heat it has the lowest capital cost (even if the payback is very long). This, coupled with the fact that it is a visible technology, may result in 'green' consumers taking this technology up, a finding in many other microgeneration studies (Whitmarsh et al 2011).

One possible issue facing the uptake of solar thermal is the trend away from the installation of hot water tanks (Table 4) reflecting the move towards combi-boilers and evidence suggests that much of the work done around building repairs/maintenance/improvement does not allow the space for hot water storage (HHWT 2010). This trend could reduce the potential market for solar thermal and other renewable heat technologies which require hot water storage to operate.

5.1.4 Biogas

The CCC (2010) highlight that the production of biogas can be used to produce high grade heat and can be a substitute for fossil fuels in a range of sectors, either through grid injection or use in CHP plants. It is primarily produced by the anaerobic digestion of waste streams, such as agricultural and food waste, but can also be produced from dedicated crops or a combination of waste. It is a relatively low cost form of renewable heat and could play an important role, although this will be dependent on its availability. The modelling carried out for the CCC by NERA suggests that there could be sufficient biogas from anaerobic digestion to generate up to 10% of total heat by 2030.

It is not clear if the best use of biogas would be for the generation of heat in buildings or for electricity and due to these uncertainties the CCC (2010) see most of the available biogas in the 2020s being injected into the gas grid. This would reduce the carbon intensity of gas and therefore be a way to reduce direct emissions within on-gas housing, whilst helping the UK to meet its renewable energy target, including potentially the target for renewable heat. Biogas injected into the grid could also eventually lead to more diversity and scope for customer preference/choice via competition with other renewable heat technologies, whilst helping to avoid the range of barriers associated with their uptake. The CCC is due to produce a bioenergy review in 2011 to consider the best use of the resource and other issues.

5.1.5 Whole system approaches

A further consideration with links to renewable heat is the development of network-based solutions that combine technologies at a local level to meet the requirements of heat and electricity, using novel approaches and/or new technologies. A current example is being developed in the Shetland Isles, which are off-gas. The Our Northern Isles New Energy Solutions (NINES) project is looking at a range of options that includes the use of domestic and large scale hot water storage. This includes installing up to 750 new water tanks and modern 'smart' storage heaters in homes across Shetland, which will be up to 15% more efficient than traditional models and will be able to store excess energy from the electricity grid and release it in the form of flexible heating and hot water to suit the householders' needs, with a mechanism to reward owners for this balancing role being investigated. They are also looking to expand the water heating storage on the current district heating project by linking it to a new wind farm development. This would allow them to store excess electrical energy from the system at times of plenty, by using it to heat water, which will then be distributed to warm local homes and businesses when needed (NINES undated).

5.2 Consumer satisfaction and issues with renewable heat technologies

As highlighted above, most studies into microgeneration, including renewable heat, tend to focus on the reasons why people do or do not install a technology, highlighting a range of perceptions about their effectiveness, costs and a range of barriers. There are fewer UK studies into user satisfaction, although some have emerged; many look at specific installations either within one building or a group of homes, but few studies look at large samples across technologies. More of this sort of data is expected to be generated in the first phase of the RHI in the domestic sector.

A study by Dobbyn and Thomas (2005) considered households that chose to install microgeneration (active, n=13) and those living in a house where it had been installed (passive, n=10). They suggest that the active householders were made up of the committed and/or those who were motivated by a love of the technology or drive for self-sufficiency. Perhaps unsurprisingly, given these underlying motivations, this group reported high levels of satisfaction with the technologies installed and a great sense of pride and pleasure. Most enthusiasm appeared to come from those with electricity generation technologies, whilst those with solar thermal were reported to be less enthusiastic, although they felt the benefits included lower costs and short paybacks.

A larger piece of research, carried out on behalf of the Scottish Government, monitored the results of a £1m funding pilot that installed renewable-based central heating systems in properties off the gas grid. It included 56 properties in the social rented sector and 31 properties in the owner occupier sector and concentrated on the use of ASHPs and GSHPs, although there were also some biomass systems installed and solar thermal was used as an add-on technology in a small number of properties. As part of the evaluation, householders' experiences and satisfaction were rated – Figure 15 (Scottish Government 2008).

The evaluation report suggested that:

- overall levels of satisfaction were high, with around 9 in 10 householders very or fairly satisfied at the end point of the project;
- around 82% were very or fairly satisfied with their system's ease of use;
- around three-quarters of householders were very or fairly satisfied with the running costs, which were found to be lower than for the heating systems that were replaced;
- noise levels attracted a relatively low satisfaction rating from those with ASHPs;
- a small minority of householders reported that the temperature on occasions felt low in comparison to the temperatures they were used to;
- most had issues with the mess and/or disruption caused to their home through the installation process (Scottish Government 2008).

Data which were collected from a further large scale study into microgeneration heat technologies (carried out by the Open University and the EST) were used in a number of separate reports including Roy et al (2008), Caird and Roy (2010) and EST (2010b). The main survey was based on over 900 households, around a third of which were self selecting, with the rest from a random selection of householders who had received grants under the Low Carbon Buildings Programme.

The first report (Roy et al 2008) highlights how renewable heat is currently largely a niche market of environmentally-concerned, older, middle-class householders who tend to live in larger rural properties off the gas grid (adopting mainly heat pumps and wood/biomass), whilst solar thermal adopters also extend into urban and suburban properties. The report suggests that over three-quarters of respondents who install a system say it performs satisfactorily and with over 90% indicating that they get considerable pleasure from using it – Table 6. It is likely that these households also have sufficient means to take advantage of the subsidies that were on offer.

Focus group work carried out as part of the Element Energy (2008) study into microgeneration, suggested that with respect to heat, participants saw CHP systems as offering the best alternative to conventional systems and that this was also the only technology that current gas heating users saw as a potentially feasible alternative.

Satisfaction indicator (1)	**Total adopters with experience of use** (2)	**STHW adopters**	**GSHP adopters**
System meets household demands for heating and/or hot water	**74% agree** 3% disagree	**71% agree** 3% disagree	**83% agree** 2% disagree
System performs reliably	**86% agree** 3% disagree	**88% agree** 2% disagree	**85% agree** 0% disagree
Get pleasure from using low carbon energy	**92% agree** 0% disagree	**93% agree** 0% disagree	**87% agree** 0% disagree
Satisfactory appearance	**87% agree** 3% disagree	**86% agree** 1% disagree	**94% agree** 4% disagree
Satisfactory instructions on operating and using system	**64% agree** 6% disagree	**65% agree** 6% disagree	**52% agree** 8% disagree
Controls provide feedback on efficient system use	**44% agree** 20% disagree	**47% agree** 19% disagree	**30% agree** 30% disagree
Satisfactory costs of running and maintaining the system	**70% agree** 2% disagree	**72% agree** 0% disagree	**58% agree** 6% disagree
Reductions in fuel bills are as expected	**46% agree** 4% disagree	**47% agree** 3% disagree	**40% agree** 6% disagree
Total responses	285	217	48

1) 'agree' and 'disagree' responses include strongly agree/strongly disagree.
2) responses from 15 woodfuelled boiler adopters and 5 biomass stove adopters are included in the total.

Table 6: Adopters' satisfaction using microgeneration heat systems.
Source: Caird & Roy (2010:66)

5.2.1 Heat pumps

In respect to GSHPs, as well as reporting high levels of satisfaction from adopters of the technology, Roy et al (2008) also reported some issues. These included a finding that only 40% achieved the cost saving they expected and that there were problems using the controls, as well as reports of slow response times of the system and/or its inability to heat rooms to the required temperature.

A heat pump trial from EST also reported that there were good levels of satisfaction with both space heating and hot water provision and there was no significant difference between users' satisfaction with ground and air source systems. However, there was some user dissatisfaction in relation to increased fuel costs, with higher levels of concern reported in social housing (EST 2010b).

A report by Carrick Housing (2010) examined the views of 30 households that had a heat pump installation. This found that around 70% of people were happy with the system that was installed, with higher levels of satisfaction among those living in flats and bungalows (92%) compared to 55% in houses. Some issues that were reported included lower than anticipated heat levels, difficulties understanding how to control the heat pumps and concerns over running costs, compared to their previous systems (although higher electricity bills also coincided with large price rises for electricity in the year they were installed, so there were difficulties separating these issues). Running costs and heat issues were more of a problem for those with retro-fitted systems, compared to new build.

NEA have also recently undertaken research to understand the fuel cost and carbon savings to dwellings converted from expensive heating systems to low carbon technologies, mainly in off-gas areas. Satisfaction data for the new heating were collected for 52 households and suggested that the great majority of households were happy with ASHPs, mainly as a result of their ability to keep the whole house warm through use of a central heating system with radiators rather than a solid fuel fire or storage heaters. Households were also found to be more likely to heat a larger proportion of their home since receiving an ASHP. Those that were not happy cited problems with keeping the dwelling sufficiently warm or that is was now more expensive to heat, although NEA suggests based on previous experience this may be attributed to increased electricity demand as a result of moving to electricity as the main heating fuel (Stockton 2011).

5.2.2 Biomass

For biomass based systems Roy et al (2008) found 90% of adopters were happy with the system once it had been installed and got satisfaction from using it. Issues raised included the need for unexpected modifications to their buildings and more disruption than they expected, as well as problems of getting a good supply of wood fuel. It was also found that fuel savings were not as high as expected and that controlling heat was hard, resulting in rooms being heated to higher levels than before.

The study by Element Energy (2008) found that people saw biomass boilers as a retrograde step, reminding people of old-fashioned coke ranges. There was also an assumption that they would need a lot of maintenance – fuelling/cleaning out etc (and respondents found it hard to grasp the concept of automatic refuelling).

5.2.3 Solar thermal

For solar thermal Roy et al (2008) found most users were 'delighted' with their system, with solar hot water being an appreciated feature in homes. However, only 47% of users said that reductions in fuel bills were as much as they expected and there were some issues such as not finding out that solar-heated water cannot be used in 'cold fill' wet appliances, or that the system was incompatible with electric showers.

By contrast, Element Energy (2008) found people thought solar thermal was unsightly and were sceptical about how effective it would be in the UK climate. The idea of having dual systems (i.e. the solar system supplementing conventional heating/ electricity) evoked negative reactions.

5.3 Barriers to the uptake of renewable heat

A range of barriers to the potential uptake of renewable heat is evident from the research above, some of which are shared across technology types, whilst others are technology specific. The possible impact of these, as well as some additional barriers, has been modelled on behalf of the CCC by Element Energy and NERA.

5.3.1 Technology-specific issues

Heat pumps

A key issue for the effective deployment of heat pumps in the UK domestic sector relates to their Coefficient of Performance (COP), essentially the amount of heat produced compared to the electricity needed to run it. COPs vary according to the magnitude of the temperature difference between the heat source and the heat load; it is calculated as the weighted average of reported seasonal performance factors, but during spells of cold weather COPs can decrease significantly (CCC 2010:207).The CCC (2010) assume current COPs of around 2.0 to 2.5, with the modelling from EE/ NERA (2011) suggesting that these could increase to around 4.5 for GSHPs and 3.5 for ASHPs in the next 10 to 15 years, and that these improvements will be necessary to make them financially attractive as a reliable heat source. They also highlight that, based in part on international experience, these levels of improvement could be feasible, although they also suggest that there is uncertainty over this and therefore there is policy risk in relying on these improvements happening.

Actual levels of performance depend on a range of factors including the type of heat pump, building insulation levels, the type of heating system and weather conditions (CCC 2010), as well as improvements to COPs. In part, performance can be improved through high quality installations, with the recent field trial by EST suggesting that performance is sensitive to installation and commissioning practices, as well as customer behaviour; within the trials GSHPs averaged COPs of 2.2 and ASHPs 1.6 (with highest measured at above 3.5 for both technologies) (EST 2010 in EE/NERA 2011). There was also concern that heat pumps can require more maintenance than standard boilers (DECC 2011i). The uncertainty about heat pump performance could be a significant barrier to their adoption, as along with high costs, homeowners may consider there is a risk of reduced thermal comfort (EE/NEAR 2011). DECC (2011i) highlight that performance will have to improve and that only installations that achieve a COP of 2.9 or more will be supported under the RHI; they have also asked EST to monitor modifications to poorly performing systems in a second round of heat pump trials. The implication of these trials is that well installed and operated heat pumps are a suitable technology for reducing emissions in the UK, so there is a requirement for improved training for installers and better information and technical support for end users (CCC 2010:207).

As heat pumps operate most efficiently as constant background lower-temperature heat distribution systems, this has implications for the type of housing that they will be suitable for, with new build offering the best potential for their use. Most existing household wet heating systems are designed for high temperature water circulation, so their use in the retro-fit market will add to refurbishment costs. The performance of heat pumps also depends on good insulation standards, so their effective deployment in the retro-fit market will depend on the projected improvements to energy efficiency being delivered, particularly in the case of solid wall houses, where the insulation is expensive and can also be unpopular (EE/NERA 2011).

Some wider issues also exist in relation to heat pumps and decarbonising electricity supply. If heat pumps are not adopted at the rate modelled, the CO_2 savings anticipated in 2030s will not be realised. Also, if the total cost of decarbonising the electricity system proves to be more expensive than projected it could result in higher electricity prices, which will have an impact on the economics of heat pumps (EE/NERA 2011).

A further issue, if there is widespread uptake of heat pumps, is their potential impact on the electricity networks as they could result in large new demands for simultaneous power[22] at peak heating times – morning and evening – with implications in terms of peak power requirements and stress on local distribution networks (EE/NERA 2011). Without mitigating measures, the changing demand profile could require major reinforcements to distribution networks and could result in new demands for peak power in the tens of GWs for very high penetration scenarios (beyond 2030), particularly during winter months which coincide with peak demand of electricity for other uses (Speirs et al 2010). These issues are being considered through projects funded under the Low Carbon Networks Fund (EE/NERA 2011) and DECC also state that they are planning to monitor usage patterns as part of their strategy for distribution networks (DECC 2011i).

Additional barriers highlighted by EE/NERA (2011) include:

- lack of trained engineers / plumbers;
- failure to achieve forecast cost reductions as the market grows;
- the need to dig up gardens for the installation of GSHPs may limit their takeup, not only to those households with sufficient space, but also because of the associated disruption, hassle factors and additional costs.

EST (2010b) have also highlighted that efficiencies for domestic hot water production were lower than expected in a number of cases, mainly in systems producing domestic hot water in the summer.

A final fundamental barrier will be whether the incentive scheme under the RHI is sufficient, given both the capital and running costs of heat pumps compared with current gas prices and likely future gas price trends, as well as the capital cost of simply renewing a boiler.

Biomass

There are a number of factors that could act as barriers to consumers in relation to biomass, such as hassle factors in relation to fuelling and de-ashing systems as well having to regularly order and store fuel, which can have associated space requirements (Whitmarsh et al 2011).

[22] A possible way around this would be combining heat pumps with thermal storage, which could lower running costs by using off peak tariffs, but there would also be barriers as storage could be large, taking up valuable space in buildings (EE/NERA 2011).

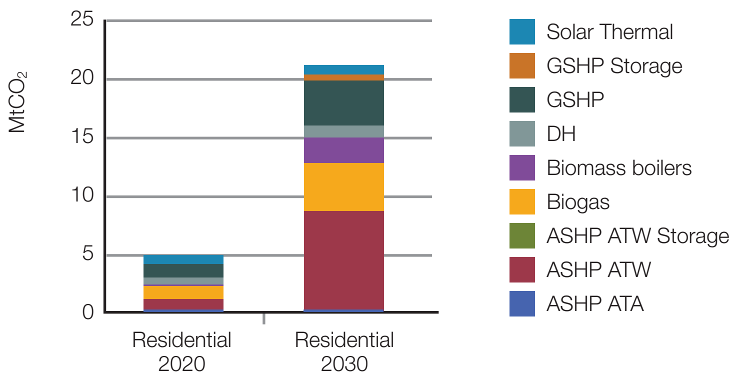

Figure 16: CO_2 abatement from renewable space heating technologies 2020 and 2030 (medium scenario). Source: CCC (2010:220)

EE/NERA (2011) also highlights barriers and risks relating to fuel, which in part relates to the limited amount of biomass fuel that can be supplied from domestic sources, meaning there will become a point when imports in the UK will be needed. This in turn will have links to price, as future costs are unknown, but as the resource becomes increasingly internationally traded, price volatility could occur. There is also a lack of a national fuel supply chain for biomass fuel, which could lead to supply restrictions in some areas, and there are wider concerns around sustainability of the resource (CCC 2011). Additional barriers identified by EE/NERA (2009) include a lack of trained designers/installers – specialist skills are needed to specify and install biomass heating systems: and air quality issues – the combustion of biomass leads to higher particulate and NOx emissions relative to fossil fuels. This can be an issue in areas where air quality is a concern (e.g. smoke control zones, AQMAs).

Solar thermal

A key issue for the uptake of solar thermal is its cost, compared to conventional sources of hot water supply. The modelling by EE/NERA (2011) suggests that the level of sales will be low under the current proposed levels of support for the technology. In addition, the CCC suggests that it may make sense to limit support for solar thermal to ensure that it does not crowd out support for lower-cost technologies with more promise for the 2020s in decarbonising emissions (CCC 2011).

A range of other potential barriers is summarised by EE/NERA (2011):

- limited suitability as the systems need to be installed on south-facing roofs to maximise output and potential difficulties integrating with existing heating systems;
- aesthetic concerns – most systems are roof-mounted and have an aesthetic impact which may be unacceptable to some householders;
- failure to achieve cost reductions will harm the economics of the technology and reduce uptake;
- lack of trained engineers/plumbers (installers).

5.3.2 High level barriers

As highlighted in section 4.5.1, a key barrier to the uptake of renewable heat options relates to the fact that they are capital-intensive with large up-front costs and can involve additional running costs compared to conventional technologies. The CCC suggest that almost all renewable heat technologies are likely to be more expensive than conventional alternatives for at least the next decade, and some will not become cost-competitive for two decades. This makes the RHI an important policy measure for overcoming this barrier to uptake. There is also a range of non-financial barriers highlighted by EE/NERA which were also summarised in the CCC (2011) renewable energy review:

- "Suitability. Renewable heat works best in well-insulated buildings, and may not be able to heat poorly-insulated buildings adequately. Scope for deployment of renewable heat is therefore limited to buildings that are currently well-insulated, or new zero-carbon homes, or those buildings that will become better insulated (e.g. under the Green Deal).
- Awareness. Given limited deployment of renewable heat to date and therefore low visibility, there is a lack of consumer awareness about opportunities for switching from conventional to renewable heat technologies.
- Consumer confidence. Given that renewable heat technologies are relatively new in UK applications confidence is currently limited. Recent trials of air-source heat pumps have highlighted potential risks of low consumer confidence
- Supply chain constraints. The renewable heat supply chain is underdeveloped in the UK, with potential bottlenecks relating both to equipment supply and installation" CCC (2011:129).

The collective potential impact of these barriers is shown in Figure 16. In terms of financial barriers, the CCC (2011) suggests that the current funding commitment under the RHI is appropriate to 2014/15, but a significant increase will be needed after this, including into the 2020s. To help overcome the non-financial barriers it is suggested that three policy levers could be used:

- Accreditation of suppliers – to ease supply chain bottlenecks, including training for installers and technology validation;
- Integrating renewable heat and energy efficiency policies – namely the Green Deal and RHI – to make the delivery landscape less confusing for consumers. This would also increase suitability as renewable heat technologies work best in well insulated houses, would enhance consumer confidence, and support the high upfront capital costs;
- Zero-carbon homes – defining these in a way that promotes the use of renewable heat (CCC 2011: 129).

A further high level barrier relates to "hidden and missing" costs, linking to the disbenefits associated with the adoption of a technology, which are not necessarily captured in capex/opex estimates. This can include issues such as:

- "Reduced level of service or inferior quality of energy service received (e.g. lost comfort from lower peak heat output, less flexibility in heat generation, etc.).
- "Hassle" or amenity costs (e.g. the value of lost space, noise, lost aesthetic amenity, damage to facilities such as gardens, etc.).
- Time costs (associated with overseeing installation, taking fuel deliveries, etc).
- Disruption to production, calibration, or other engineering-related costs" (EE/NERA 2011:12).

Work by Element Energy in 2008 examined some of the hassle factors to estimate potential additional costs for heating systems, based on work with consumers around willingness to pay (WTP) (EE/NERA 2011). They highlight that monetising such costs is inherently difficult, but a range of estimates for some hassle barriers is included within their modelling – Figure 17, suggesting possible monetary values for some hidden costs:

- £1,000 for domestic ASHP and GSHP installations to reflect the loss of space due to the need to install large radiators;
- A further £1,600 for GSHP installations to reflect the inconvenience of digging up the garden;
- £1,250 for biomass boilers to reflect the space and refuelling issue[23].

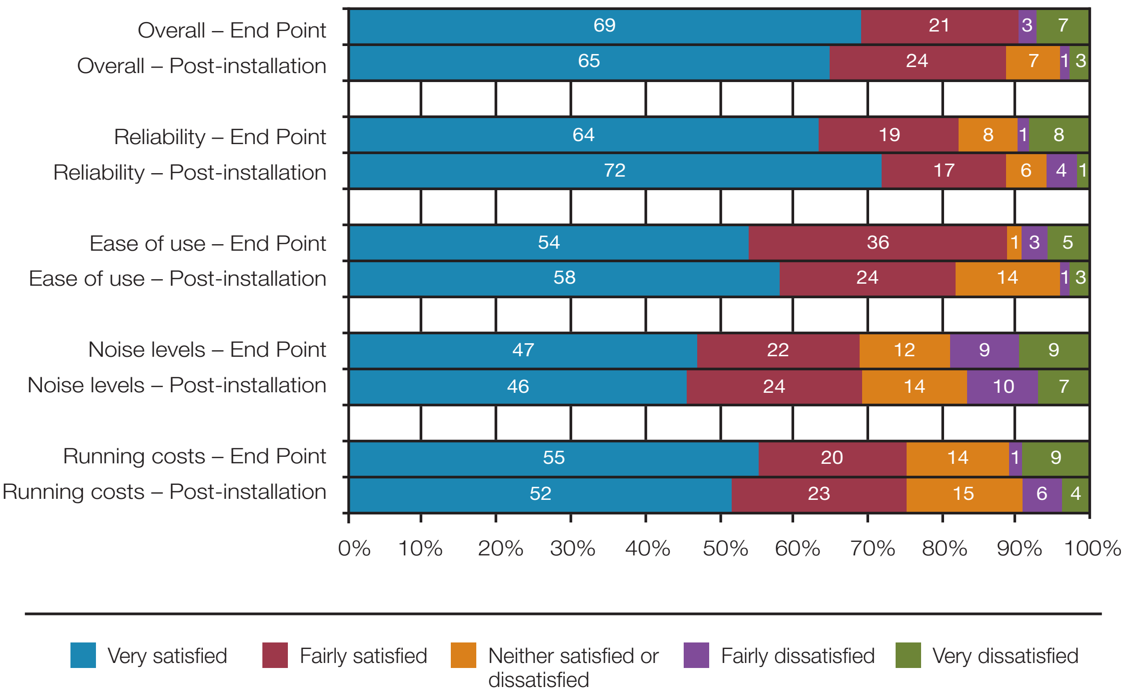

Figure 17: Scottish renewable pilot satisfaction levels (post-installation and end point questionnaires). Source: Scottish Government (2008:7)

[23] This also shows the positive effects that recommendations from trusted sources can play.

5.4 Options for increasing gas efficiency

Given that much of the focus on decarbonising heat in the domestic sector, through the uptake of renewable heat, is likely to focus on new build, off-gas and possibly major refurbishments up to 2030, the most significant way to decarbonise heat in the domestic sector pre-2020 and pre-2030 will be through maximising the efficiency with which gas is used. In addition to improving the overall efficiency of the housing stock, through better fabric insulation and behavioural measures, other options for on-gas housing could include more efficient boilers, better controls, and the possible adoption of new technologies outlined below. Given the high penetration of gas and the apparent satisfaction that is shown towards it, and recognising that alternatives face a wide range of technical, financial and social barriers, such measures could play an important role in decarbonisation.

5.4.1 Increasing boiler efficiency

The HHWT (2010) suggests that of the 21.6 million gas boilers that are installed in UK homes, only around 27% are condensing boilers[24]. This suggests that there are still over 15 million inefficient gas boilers in use. The industry also suggests that this could include over 4m G-rated boilers and 2m F-rated boilers[25]. The potential carbon savings from upgrading these could be significant, with EST (2008) highlighting that an A-rated condensing boiler can cut emissions from heating by up to a third. In the evaluation of the boiler scrappage scheme, it is suggested that the 118,618 boilers that were installed will result in savings of 240,000 tonnes CO_2/year (EST/TNS 2011) – around 2 tonnes per installation[26]. 85% of these savings are from boilers themselves.

The Heating and Hot Water Industry Council suggest that, without intervention and based on current rates of replacement, over 4m homes could still be using non-condensing boilers by 2020. The industry welcomed the boiler scrappage scheme, but highlight that this replaced less than 1% of all the inefficient boilers and they suggest that further financial incentives through an extended scrappage scheme, supplier obligation, promotion under Green Deal, (ECO) and reduced VAT could all help increase the speed of uptake (HHWT 2010).

Although the gas boiler stock is expected to improve in efficiency through natural turnover to 2020, efficient boilers can save around 30% on fuel so there is considerable near-term scope for incentivising and supporting, through better information, their uptake, particularly as there could still be 4m non-condensing boilers in operation by 2020. Policy should also focus on the considerable scope for improving controls, thermostats and thermostatic radiator valves (TRVs) to enable further efficiencies. Such a policy would help to deliver affordability, comfort and carbon savings.

5.4.2 Improving controls

The HHWT (2010) highlight that efficiency of central heating can be enhanced through use of better heating controls[27] enabling required levels of comfort to be reached with the least amount of energy. EST (2008) suggests that a full set of heating controls will save around 1.7 tonnes of CO_2 a year, whilst reducing bills by as much as 17%. Analysis by BEAMA, based on EST and EHCS data, indicates that of those homes with a boiler, 38% do not have room thermostats, 45% have no TRVs and 71% are missing one or more control types, rising to 75% in homes that do not have a condensing boiler (HHWT 2010:41). At a UK level, work by the Association of Control Manufacturers and EST suggests that: nearly 8m UK homes with a boiler do not have a thermostat; over 70% don't reach the minimal levels of controls as set out in the 2010 building regulations; 800,000 homes with a boiler have no controls at all, which if rectified would equate to potential UK annual carbon savings of 4.3 $MtCO_2$ – about the same as identified for loft insulation (HHWT 2010:44).

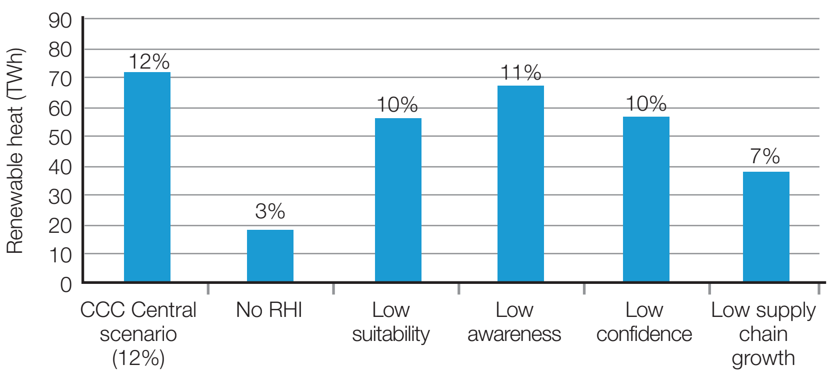

Figure 18: Impact of barriers on renewable heat penetration in 2020
Source: CCC (2011:130)

[24] For oil it is suggested under 7% are condensing

[25] They do not distinguish if this includes both gas and/or oil.

[26] This is based on the average boiler replacement being brought forward by 1.4 years, and EST estimates for replacing a G-rated boiler with an A-rated boiler. Additional savings came from the associated installation of boiler controls.

[27] Heating controls comprise time programmers and a room thermostat or a combined programme room thermostat, plus cylinder thermostat if appropriate and TRVs (HHWT 2010:41)

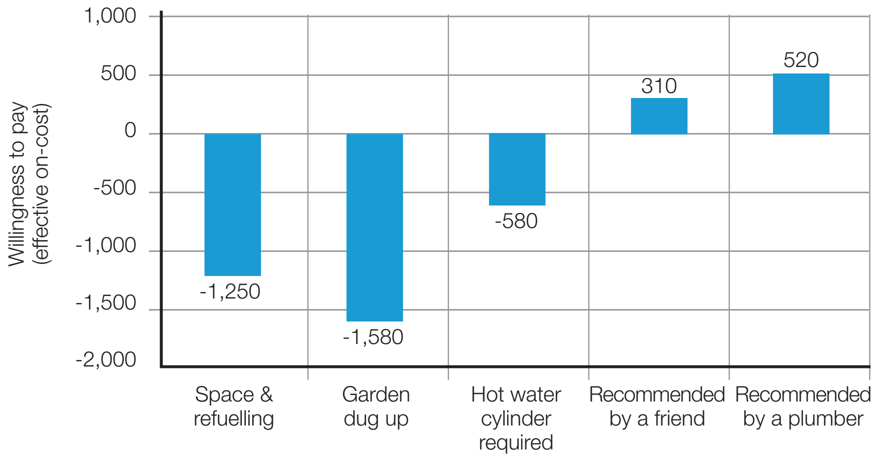

Figure 19: WTP for heating system attributes based on 2008 survey work
Source: EE/NERA (2011:22)

A range of barriers for matching heat delivery and hot water provision to actual usage requirements has been discussed by the HHWT, including technical, practical and behavioural aspects, as well as the potential to link controls with micro-renewables. However, they highlight that controls are relatively low cost measures that pay back quickly. To overcome the barriers, the HHWT (2010) suggested that: a target for all existing homes to have a cost effective upgrade to their heating and hot water controls up to the minimum level in the 2010 building regulations should be introduced; calculation methods for estimating the benefits of controls should be developed; industry and Government should work together on communication to consumers; installers should advise on control solutions to their customers; and a suitable controls specification should be agreed between industry and Government and implemented for the 2013 building regulations (HHWT 2010).

5.4.3 Passive flue gas heat recovery
This technology is at the early stages of development and provides additional system efficiency by recycling flue gas heat which would normally be wasted. The reclaimed heat is used to pre-heat the incoming cold water, increasing hot water efficiency whilst lowering gas consumption. Savings are estimated at around 30% of gas used for hot water and typically 0.5 tonnes of CO_2 per annum. Payback time is estimated at five years and it is a technology that would be suitable for most on-gas properties. Currently sales are around 9,000 units a year, mainly in new build and social housing, but projected sales could be in excess of 1m per annum (HHWT 2010).

Barriers to adoption include: market/consumer awareness and understanding of the technology; the additional cost of around £500; size and space requirements; benefits are currently capped in SAP; and available only from three boiler manufacturers. These barriers are likely to inhibit the market potential in the short term. It is suggested that campaigns to raise consumer awareness and financial incentives could help overcome these barriers (HHWT 2010). It is also possible that installer training is required to ensure the technology can be effectively integrated.

5.4.4 Micro-CHP
This is another potential emerging technology that can provide enough space and water heat for most normal housing plus an electricity output of up to 1 kW per hour. There is a range of different technologies available[28] with typical installed costs of around £5,500. They can be used instead of conventional boilers and although running costs will be higher, this is at least in part offset by the production of electricity (they are also eligible for FiTs) (EST 2011a).

The HHWT (2010) highlight that they can save around 700–800kg CO_2 per year, compared to an A-rated boiler, whilst Centric suggest forecasts show this could rise to around 2.5t CO_2/year, in addition to saving around 25% on household fuel bills (Centric in HCECC 2010). With a typical electrical power output of 1 kW, every million homes equipped with micro CHP would effectively provide 1GW of low-carbon generation capacity As they also generate power when there is a demand for heat and hot water, this coincides with peak demand on the grid when carbon intensity is currently at its highest which would bring additional economy-wide carbon benefits (HHWT 2010).

[28] The range of different technologies includes: Internal combustion engine driven generator; Stirling engine driven generator; Organic Rankine Cycle generators; fuel cells – they have different levels of suitability within the domestic sector (HHWT 2010).

Element Energy (2008) in HHWT (2010) suggests that total sales as of 2008 were less than 1,000 units and that annual sales in 2007 were less than ten. However, micro CHP has a mass market potential in the domestic sector, with the possibility to replace around 80% to 90% of existing boiler sales (HCECC 2010; HHWT 2010). The technical potential by 2020 could be 900,000 units/yr, with the actual number of installations likely to depend on policy intervention; with limited support sales are expected to be much lower by 2020, in the region of 50–100,000 units per annum (HHWT 2010).

Just as with heat pumps this is not a technology that is established at scale and a number of barriers to takeup will therefore exist. These could include: cost, although manufacturers are forecasting this could fall as volumes increase; the limited numbers of products available on the market; some installer resistance[29]; the need for increasing consumer awareness; and the need for SAP to fully credit and reward the performance and savings delivered. In addition, the HWWT (2010) question the need for Microgeneration Certification, given that there are already existing and well established routes for boiler installations and product and installer certification. Possible ways to overcome these include increased support under FiTs (15p/kWh instead of 10.5p/kWh) plus the export tariff; promotion in other policy measures, such as Green Deal; and linking to building regulations by requiring installation under Part L (HHWT 2010).

5.4.5 CHP and district heating

The CCC (2010) highlight that CHP can increase the overall efficiency of energy production, by making use of the otherwise wasted heat from thermal combustion either directly on-site or via district heating systems. Heat can also be delivered from large scale district heating boilers. Such heat networks have a low penetration in the UK, currently providing around 1% of heat, mainly from fossil fuels. An issue for their development is that production is often located a long way from where the heat is needed, resulting in potentially large infrastructure investment costs. In the Fourth Carbon Budget, the CCC concluded that there is a high degree of uncertainty around the technical and economic aspects of district heating based on low carbon CHP, but that it may be a promising option that needs further consideration.

A range of fuel inputs can be used including gas, biomass or low carbon generation, at a range of scales, and it is suggested that there may be near-term opportunities for reducing emissions through gas CHP, although in the longer term low carbon power generation would be more preferable (CCC 2010).

5.4.6 Gas heat pumps

Gas heat pumps (GHPs) are also being developed for heating applications and it is suggested that they could cut energy consumption and CO_2 emissions by up to 30% (EoN 2011). Within the UK, work by Warwick University to build and test a gas heat pump suggests that COPs may be quite low (1.5) (CALEBRE 2011), compared to electric heat pumps, but they would still be more efficient than conventional gas boilers and they also appear to offer an advantage in being able to rapidly respond to demand. In addition, the uptake of GHPs would reduce overall load on the existing gas supply infrastructure because of their greater efficiency, whereas the widespread uptake of electric heat pumps will increase pressure on electricity networks. As such, Warwick suggest that a balanced mixture of electric and gas powered technologies could be prudent and secure, by increasing diversity in the energy system (CALEBRE 2011). Gas heat pumps could also use renewable gas.

There is considerable attention being given to GHPs in Germany, with the gas industry working with appliance manufacturers in a joint Gas Heat Pump Initiative to further develop this technology to market maturity through practical laboratory tests and field trials. Four manufacturers are involved in installing and testing up to 250 GHPs. The first results from the tests appear to confirm a potential for the technology for larger buildings and multi-family housing – i.e. only competitive if largeish scale (new and existing buildings), with testing for the wider market such as new single-family homes currently taking place (Werner Weßing & Ramesohl, undated).

Despite the potential that GHPs may offer, their potential role in providing heat in the UK is unclear. In many respects the technology could face exactly the same barriers that electric heat pumps face, such as running costs, capital installation costs, the need for high levels of insulation, etc. Also, if gas prices were to rise considerably relative to electricity prices over the next twenty years, this could prove to be an expensive option.

[29] It is suggested this is no different from when condensing boilers first emerged (HHWT 2010).

6. Conclusions

Based on the research questions from Scotia Gas Networks, we have analysed and considered a number of key issues with regard to the fuel and technology choices for heat within the domestic sector. This has taken account of trends over the last 20 years to understand how heat services have been met, how heat is currently provided and how this may change in the future. From this it has been possible to examine some of the underlying factors that play a role influencing consumer preferences for heat. Based on Scotia Gas Networks' research questions we suggest that:

1. Gas is the dominant fuel for providing heat in the domestic sector and is likely to remain so for some time

The data clearly show that gas is the dominant fuel for providing space and hot water within the domestic sector. Around 84% of homes are on the gas network and gas consumption, having increased year on year until around 2004, now appears to have peaked, suggesting that the market is saturated. The share of gas in providing heat varies by end use:

- for space heating gas currently meets around 83% of the UK domestic sector's consumption;
- for hot water gas currently provides around 78% of final consumption;
- for cooking gas currently meets around half of the final consumption.

2. A range of technologies is available to provide heat, but wet-based central-heating dominates

There is a range of different technologies used to meet the need for heat, reflecting different end uses. For space heating and hot water, most homes in GB currently use wet-based central heating systems to provide both these services. Over 92% of homes have central heating and it is estimated that 85% of these use gas based systems. However, electricity does play a greater role in meeting some of consumers' demand for hot water. For cooking, hobs are predominantly gas, whereas ovens are more likely to be electric, reflecting the more even split in fuel use.

3. There is a wide range of factors that currently influence fuel and technology choice

There is a lack of direct research into consumers' preferences for the provision of heat within the domestic sector, but a number of underlying factors play a role in influencing choice. Some are outside the control of consumers, relating to structural issues such as dwelling characteristics, type of tenure and importantly whether there is access to gas. Beyond this, it is apparent that there is a preference towards systems that are easy to control and maintain, are reliable and familiar, and that can meet the desired levels of comfort as and when required. Capital and running costs also play an important role as consumers seek to spend no more than is necessary to get a system that meets all their needs. For all of these reasons, gas based central heating systems that provide both space and hot water requirements dominate the existing domestic market and high levels of satisfaction are shown for these types of systems.

It is apparent from the growing body of work on attitudes, behaviour and behaviour economics that people do not follow rational choice models. Instead there is a tendency to discount future benefits, use defaults and be influenced by social norms. These not only limit the uptake of measures, but also influence people's energy use behaviour, with evidence to show that people are willing to do things only if the level of disruption or lifestyle change is limited and the quality of life remains similar. The fact that people are essentially seeking technologies and fuels which are cost effective, easy to install and run and are reliable, easy and compatible with their current systems and lifestyles helps explain the high levels of satisfaction with gas. There appears to be an effective 'default' to gas which manifests itself as seeming inertia, in particular in on-gas households and also in relation to space heating, where there is considerable inertia for householders to retain gas.

One potential way to address the 'default to gas' is to work with natural intervention or trigger points. These include before and during renovation work, either on an ongoing basis during people's occupancy of a property or when a property is purchased. However, most work around these intervention points is based on energy efficiency and the findings may therefore not be transferable to renewable heat, given that the installation of these is generally more costly and disruptive than energy efficiency measures.

Combined, these issues make understanding choice complex, which is further overlaid by cost. Many decisions to replace heating may be rapid, i.e. because of equipment failure, reducing the likelihood of a replacement being a 'considered choice'. Even then, the relative cost difference when replacing a gas boiler with an alternative technology is significant, particularly in terms of upfront capital costs and potentially on-going running costs, particularly in existing housing stock, even with the provision of subsidies through Green Deal, the RHI or FiTs.

For water heating, there appear to be more genuine options for choice, such as using electricity for showers or via immersion heaters. It is also apparent that there is a growing tendency to install combination boilers, partly to save space within the home by removing the need for a water cylinder. If this trend continues it has the potential to curtail some alternative forms of integrating thermal storage and renewable heat at the household level, as well as the potential macro options such as using thermal water storage to make use of excess wind power.

For cooking, although modest in terms of total energy use, there is a preference towards the use of gas hobs, linked to quick response and flexibility, and for ovens a trend towards electric models which are perceived to provide a more even heat. The desire for gas hobs may result in developers, even under future scenarios for 'zero' carbon homes, opting to connect new homes to the gas network.

4. Consumer preferences could be a significant barrier to the uptake of renewable heat

Given that consumers are generally satisfied with the way that heat is currently provided within the domestic sector, policies to encourage and enable a shift to renewable heat will face a number of barriers. Some of these have emerged from the limited number of studies that have taken place with those consumers who have had renewable heat installations, and others have emerged through modelling and focus group work. Many of these studies actually show there is a high level of satisfaction with renewable heat (space and water), but for a number of reasons, it is not possible to objectively extrapolate these findings in respect to the large-scale uptake of renewable heat. This is because:

- most studies just look at off-gas households;
- they have tended, in the case of early adopters, to comprise environmentally or technologically motivated, middle class, older consumers (with sufficient funds to pay for the equipment);
- some studies are focussed on social and/or fuel poor, housing where the capital costs for installation have not been paid for by the occupier;
- some studies have collected data from households which were having central heating installed for the first time therefore observing a change in a wide variety of system parameters.

In respect to potential barriers, these studies and the wider work, particularly for the CCC, show a number of potential barriers to renewable heat uptake, which are summarised in Table 7.

5. There is a lack of clarity about how government sees the role of gas evolving in the domestic sector through to 2030 and beyond

There are a number of policies that are taking down a more electric future for domestic heat. Pre-2030 there is considerable scope to maximise the efficiency by which gas is used, given its dominance in existing housing and the high levels of consumer satisfaction with its use. More policy attention is needed to both ensure the replacement of inefficient boilers and promote better controls, which would reduce carbon, whilst simultaneously increasing affordability and comfort, particularly to 2020 and also 2030.

Key findings and recommendations

In order to address the threat of climate change the UK has set an ambitious carbon reduction target, alongside a target for increasing the share of renewable energy by 15% by 2020. These targets have become the key drivers in shaping

Technology	Issues found	Additional barriers to uptake
All	• disappointment in the level of fuel savings achieved • issues with the amount of disruption caused during installation	• high upfront capital costs and long payback periods and a risk of projected declines in cost not being achieved • hidden and missing costs • lack of awareness or understanding of different options • lack of suitability, particularly in terms of energy efficiency of housing • consumer confidence in new technologies • lack of credible installers and suppliers and other supply chain constraints • hassle factors associated with having work done, or for ongoing operation • concerns about ease and costs of maintenance
Heat pumps	• concerns over running costs, although this in part may reflect the switch to one heating fuel or heating the whole home • mixed views on their ease of use and ability to control • concern over noise for ASHPs • lower temperatures than desired	• uncertainty over improvements in COPs • poor installation standards • high levels of maintenance • the need for high levels of energy efficiency • the potential need for new heat distribution • the need to dig up gardens for GSHPs • failure to meet hot water demands
Biomass	• difficulties in control • securing reliable fuel suppliers • perceived concerns over maintenance and hassle for fuel and cleaning	• space requirements for fuel and equipment • uncertainty on future fuel prices • sustainability of fuels • air quality issues
Solar thermal	• mixed views on their visual appearance • actual and perceived integration problems	• limited suitability – roofs and integration

Table 7: Issues and barriers highlighted in renewable heat studies and modelling

the direction of UK energy policy and a range of models and scenarios has been developed to examine the options for achieving this. Analysis by Government, its advisors and others points with increasing consensus to a need to increase energy efficiency, decarbonise the power sector and expand the use of electricity into heat and transport. Policy developments have increasingly sought to enable this to happen both pre- and post-2020 and a vision of a far more electric future now appears to be significantly shaping policy.

Of the policies, measures and incentives that are in place and being developed, to meet the UK's carbon and renewable energy targets, many will improve thermal insulation within the domestic sector, notably CERT, CESP, Green Deal and ECO. As such, towards 2020 policy will help to reduce demand for gas (and electricity) making their use more efficient and cost effective for consumers. In the case of gas, these measures will also reduce the direct emissions from the domestic sector. However, further and significant near-term gas savings could also be achieved by the active promotion of additional cost-effective measures focused directly on improving efficiency of household gas-use, particularly through better controls and ensuring boiler upgrades.

Beyond increasing efficiency, it seems that other incentives, such as the RHI, FiTS, and Zero Carbon Homes, are currently more oriented towards the promotion of electricity, at the expense of gas, given that, post-2020 and beyond, policy is seeking to encourage households to adopt electricity for heat. The scale of the anticipated step-up to household electrification post-2030 is substantial, as is the transition in terms of where we are today in terms of gas dominance of household space-heating and hot water. The aspiration level for electric heat implied by the UK's carbon targets, and Government acceptance of this direction of travel, is currently not underpinned by an economic analysis of the likely impact on households of a large-scale switch from gas to electric heat in the 2030s, nor by an evaluation of the likely role of customer preference and choice.

Given where we are today, questions arise as to how readily achievable the shift to greater electrification may be. Up to 2030, interventions and incentives need to take more account of the potential to achieve substantial carbon savings from household gas savings. Any such savings will also have a knock-on impact on (1) the comparative economics of eventual household substitution from gas (including renewable gas) to electricity (2) likely customer choice and (3) the residual level of carbon savings achievable from electrification of heat. Significant household gas savings pre-2020, could influence the comparative cost-efficiency of uptake of low-carbon and renewable electricity technologies for households longer-term.

The UK needs to decarbonise its economy and this requires action within the domestic sector. However, options in respect of domestic heat need to be kept open and fully explored before locking into a system that householders may find unappealing. The risk is that existing households may become a significant hurdle to a more electric future for heat which in turn could impact on the UK's ability to meet its 2050 target. The majority of domestic consumers use gas, because it is in place and because customers are generally broadly satisfied with relative price, convenience and comfort. The focus of policy is on carbon, but from a consumer perspective this risks an unsolicited choice for the longer-term between electricity and gas. Gas, and the technology that supports it, is understood and liked, whereas alternatives may face teething problems plus cost and other barriers. A first step must therefore be to give priority to measures that maximise the efficiency of gas, particularly as household gas use currently accounts for around 14% of all UK GHG emissions. This could include upstream measures to reduce losses and make more use of biogas, which would also help to avoid the range of barriers associated with alternative forms of renewable heat; as well as the very considerable downstream scope with respect to replacing inefficient boilers, installing better controls and supporting the development of newer technologies. Until the picture for technology and fuel choice for household heat is both better quantified and better understood from a consumer perspective, there is a risk that more expensive pathways to decarbonisation are incentivised at the expense of alternatives which may be both cost-effective and attractive from a customer viewpoint. Near- and medium-term investment decisions – both by actors in the gas sector and by individual households – need to be underpinned by a more strategic view of the role anticipated for gas in the UK energy system in the future, including for household gas.

Based on these findings we suggest that:

- there is a need for further direct work with consumers to understand their underlying preferences towards the provision of heat, hot-water and cooking, in particular in on-gas housing;
- there is a need for further analysis, including likely cost and emissions savings, based on a more efficient role for gas within the domestic sector;
- there is a need for further work on how customer preferences will have an impact on the various Government models;
- Government has a central role in directly communicating the potential changes to how consumers may meet their heat needs in the future;
- Ofgem should carry out further work around consumer preferences with respect to heat through their consumer panels.

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About Us

Scotia Gas Networks (SGN)

We transport natural gas to 5.8 million customers through our network of 74,000km of pipes. Our network area covers 40% of the UK landmass and our vision is to be the leading operator of gas networks in the UK.

Our Scottish network distributes gas across all of Scotland to 75% of households as well as commercial and industrial sites. This includes remote areas not connected to the national gas network referred to as the Scottish Independent Undertakings (SIU) which are Stornoway, Wick, Thurso, Oban and Campbeltown.

Our Southern network stretches from Milton Keynes in the north, to Dover in the east and Lyme Regis in the west, including London boroughs to the south of the river Thames, distributing gas to around 90% of households and many commercial and industrial customers.

With environmental issues and sustainability as core values, we commissioned the University of Exeter to carry out this research into how consumers fit into the evolving energy debate with a particular focus on the use of gas. We will use the results of this study to feed into our business strategy and we hope the results will also inform the wider energy debate.

For any further details from us relating to this study please contact:

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The University of Exeter Energy Policy Group

The Energy Policy Group (EPG) at the University of Exeter provides an academic hub for the interdisciplinary study of energy policy and sustainability, specialising in the transition from the current unsustainable energy systems to sustainable ones. The EPG sees itself as undertaking cutting-edge, policy-relevant and evidence-based research thereby providing objective research, analysis and policy advice to policy makers, industry, NGOs, and the public. The research work of the group is currently funded by grants from UK research councils, the European Commission, the Danish Government and also through consultancy with national and international stakeholders.

Research carried out by the group is interdisciplinary and collaborative, both within the University and with outside organisations and individuals. It has developed a powerful group of associate fellows to enhance its research. In addition to research, the group run the MSc Energy Policy as well as contributing to the MSc Climate Change and Risk Management and the undergraduate Geography degree programmes at the University. There are also a number of PhD researchers contributing to the group.

The EPG also runs the annual Falmouth Energy Week. Finally, the EPG produce policy proposals, research reports, responses to government consultations on energy and climate change, consultancy reports, conference and journal papers, presentations to a wide variety of audiences, and contributions to the wider debate in the general media (press, TV, radio and internet). They also engage in international fora.

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