energy technologies institute

An insights report by the
Energy Technologies Institute

Smart Systems and Heat

Consumer challenges for low carbon heat

Contents

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Key headlines

- ETI consumer research highlights issues to address if the UK is to change how it heats the vast majority of buildings
- Today fewer than 4% have low carbon heating and 90% prefer gas central heating
- Location constrains the heating solutions available to each building and existing buildings have their own constraints
- People are diverse, they want different things from their heating (for example cost, comfort, health) – the same solution will not suit everyone
- Improve low carbon heating designs so they tackle common problems and enhance home life
- Simplify installations so they are more convenient
- Enhance heating control so people can value what they spend, get what they want from low carbon systems and factor heat into renovation decisions

Executive summary

The UK will need to all but eliminate emissions from domestic heating to meet its carbon targets.

Previous emissions reductions have been relatively simple, cheap and delivered clear benefits to households.

But the options currently available to make further reductions would require households to endure more disruption for less obvious benefits. Policy makers are likely to be reluctant to force changes in people's homes that are widely unpopular.

We need to develop ways to reduce emissions from domestic heating that are more appealing to consumers, thereby making the transition to low carbon heating much easier to deliver in practice. These solutions will need to be underpinned by sound engineering; high quality design; appropriate technical, consumer and economic regulation; and financially viable business models.

The Energy Technologies Institute's (ETI) Smart Systems and Heat Programme (SSH) has conducted a range of in – depth consumer research to inform the design of holistic solutions. The findings revealed three key consumer challenges for the transition to low carbon heating.

1) Improve low carbon heating experiences

Historic experience shows that widespread change in domestic heating can be achieved when new options deliver a better experience for consumers.

The proportion of homes with central heating rose from 25% in 1970 to 90% in 2006. Many paid to install central heating, despite the disruption, as it was better than what they had before.

Today, fewer than 4% have low carbon heating and 90% prefer gas central heating given the choice. More may want low carbon heating if it offers an improved experience at home.

Requirement – Low carbon heating designs should improve heat experiences and allow people to get clean and comfortable in diverse ways.

Consumer research clarifies what people want from their heating today and highlights how to make future low carbon heating solutions attractive.

- Almost everyone uses heating to get clean and comfortable at home, but they do so in different ways.
- People's preferences for heat and hot water vary significantly, and people with different preferences can live in any home.
- People are less aware that they also use heat at home to enhance health, enrich relationships and protect property.

Low carbon heating would be more attractive to consumers if it tackled common problems and improved home life more broadly.

- About two thirds of people complain about draughts and damp, and a similar proportion take steps to stop overheating in winter.

Executive summary

Continued »

2) Make low carbon heating simple to prepare for and install

More households will install low carbon heating, or prepare their properties for it, if this can be done conveniently when replacing their heating system or improving their home.

Low carbon heating options may require substantial extra work in or around buildings to work effectively (often involving upgrades to electricity supplies or new heat network connections, as well as disruptive work on insulation and/or draft-proofing).

- People often invest in their heating systems when gas boilers break or get close to their end of life.
- Many consumers will want a new heating system before they have prepared their home (e.g. by improving insulation) for a low carbon alternative. Workable interim solutions could help to displace gas heating more quickly.

Requirement – Workable low carbon heating options should be designed so they can be installed in a similar timeframe to a gas boiler replacement.

It would be less disruptive to prepare buildings for low carbon heating systems alongside other home improvements.

- One opportunity comes when people renovate their properties as 35% are planning renovations at any time and 70% of plans take over a year to finalise.
- More will want to prepare their properties to add near term value than reduce long term running costs as 90% renovate to improve their homes.
- Householders and installers struggle to make informed decisions about thermal details during renovations.

Requirement – People need to know what solutions will work in their area and how to prepare their homes for low carbon heating systems.

3) Make heating easier to control

Low carbon heating will be more attractive if people can control systems easily to get what they want from their heating.

Most people express concern about energy bills and waste in some way, but they also have very different approaches to using heat at home. Most people struggle to relate what they do at home, to the heat they use, or the energy bill they pay.

- People hold different views on how heat should be used. 36% care about how much they use to get comfortable, 9% put more emphasis on their and 18% others' comfort, 37% are relatively disinterested in heating.
- Most consumers hardly consider cost when using heat at home – heat consumption is generally a by-product of daily life, rather than a conscious choice.
- Few households realise they use, on average, 80% of their energy for heat and hot water, costing around £15 per week (estimated annual average in 2014).
- People find heating hard to control as there is often a delay between adjusting a setting and feeling the effect. This delay is fairly short for gas boilers, but longer for heat pumps which early adopters find harder to control.
- In future low carbon heat solutions could have different cost structures. Advanced controls could allow people to buy heat when it is cheap to store in the home for later use.

Requirement – Controls for low carbon heating should make it easier for consumers to get the experiences they want in their homes.

Next steps

Converting around 30 million homes in the UK to low carbon heating by 2050 is a massive challenge. Developing coherent answers to the three challenges set out above will make this transition much easier to deliver in practice. These challenges will inform the ETI's ongoing SSH programme in:

- Working with industry to stimulate improvements in the design of energy services, heating systems and controls;
- Building evidence of what improved technologies can deliver and developing plans for where to deploy them in specific areas;
- Supporting the debate around how policy and regulation can enable the transition to low carbon heating.

Context

Lower carbon heating must appeal to households if the UK is to meet its carbon targets so it is critical to understand why people use heat and hot water at home

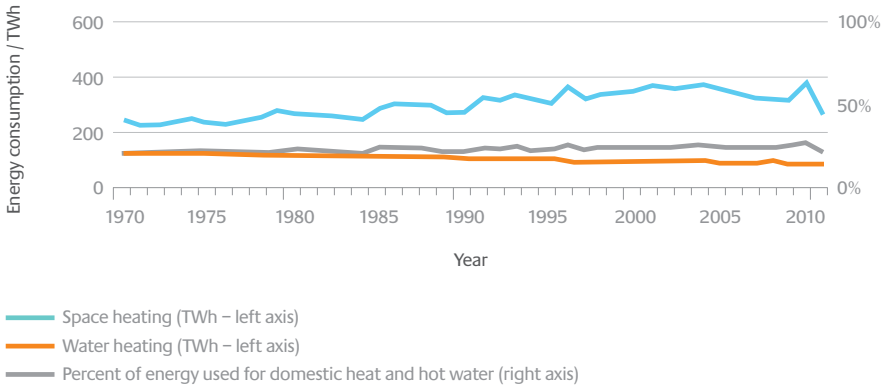
The proportion of UK energy used every year on domestic heating and hot water has remained remarkably constant at around 25% since 1970. However, the way this heat has been used has changed dramatically as households have installed central heating, heated more of their homes to higher temperatures and replaced baths with showers. Households have overall used much more heat without consuming much more energy because they have installed more efficient boilers and lived in increasingly well insulated homes (see Figure 1).

Today about 20% of UK CO_2 emissions come from how people use heat and hot water at home.[1] These emissions must be effectively eliminated by 2050 to meet carbon targets at the lowest cost.[2] The Government's plan involves every household installing lower carbon heating like district heating or a heat pump.[3]

Progress is slower than required.[4] These technologies were available in 1970, but less than 4% have them today (see Figure 2). Deeper decarbonisation may become increasingly challenging as 90% of households would prefer a gas boiler to a low carbon alternative given the choice.[5] Stronger regulations or subsidy might accelerate uptake, but strongly encouraging people to make changes they dislike could prove unpopular.

FIGURE 1

UK Energy Consumption in TWh from 1970 – 2011[6]



[1] CCC (2014) Meeting Carbon Budgets – 2014 Progress Report to Parliament.

[2] Deeper cuts in domestic emissions minimise the overall costs by allowing higher emissions to remain in areas that are more expensive to decarbonise.

[3] DECC (2012) The future of heating: a strategic framework for low carbon heat.

[4] CCC (2014) Meeting Carbon Budgets – 2014 Progress Report to Parliament.

[5] DECC (2013) Home owners' willingness to take up more efficient heating systems, p56.

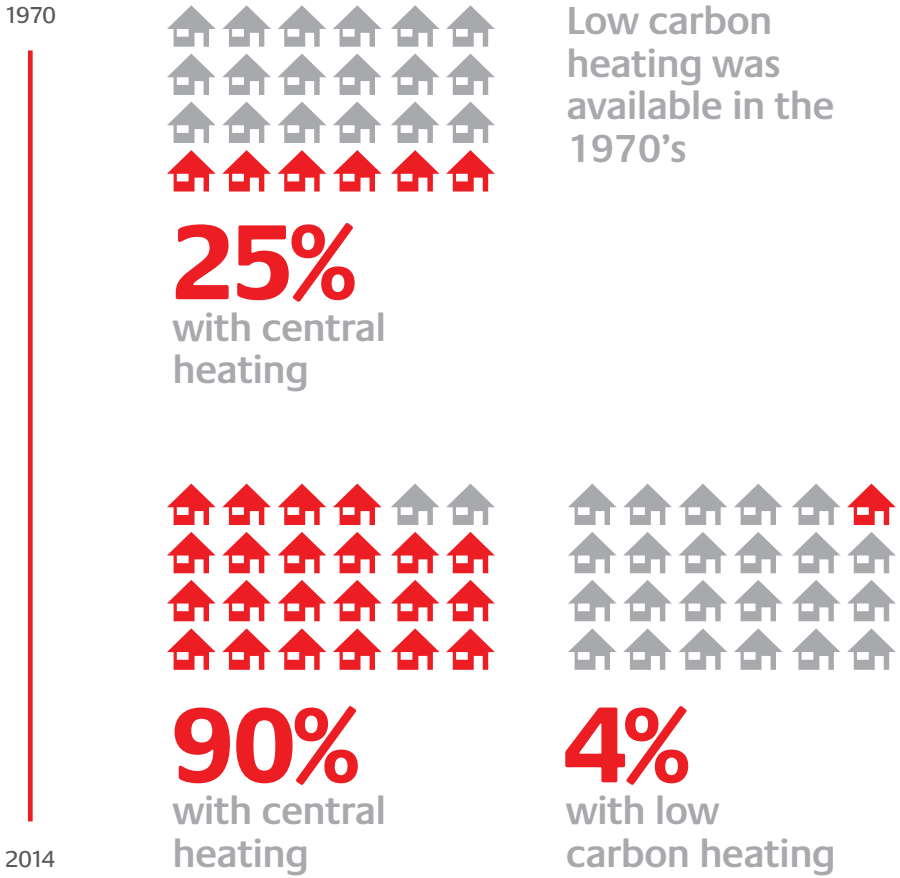
[6] DECC (2012) Housing energy fact file.
Mavrogianni et al. (2011) Historic Variations In Winter Indoor Domestic Temperatures and Potential Implications For Body Weight Gain. Indoor and Built Environment, 22 (2), 360-375.
Walker (2009) The Water and Energy Implications of Bathing and Showering Behaviours and Technologies.

Context

Continued »

FIGURE 2

Household uptake of low carbon heating



The ETI's research on how people use heat at home

The ETI's Smart Systems and Heat (SSH) Programme takes a holistic approach to solving these challenges. It started with five stages of extensive consumer research to understand what people want heat and hot water for at home. A subsidiary aim was to explore why people upgrade their heating systems.

It is difficult to understand domestic heating as people cannot easily link what they do at home to the energy they use. This adds considerable cost and complexity to gathering a robust enough understanding of people to design successful heat policies and commercial propositions.

This insights report sets out the key implications of existing evidence. It includes findings from our research and cites the original sources of those published elsewhere. New data and ongoing analysis will continue to provide further clarity in coming years.

Stage 1

Built on existing knowledge by reviewing ~350 papers on domestic heat use and ~150 papers on comfort;

Stage 2

Discovered areas of consensus and contention by discussing heat with 32 groups in full day workshops involving 153 participants in four parts of the country;

Stage 3

Visited 30 households four times over a year to reveal how home life shapes heat use: we used sensors to see beyond what people said, to what they actually did; and we modelled eight of these homes to relate their behaviour to energy used;

Stage 4

Quantified variation in heating practices by surveying and observing a representative sample of 2,313 British households for an hour in their homes using a method informed by learning from stages 1-3;

Stage 5

Visited 33 households living with high levels of insulation, district heat and/or heat pumps to evaluate how well low carbon technologies perform today; discussed what people expect from smart heat technologies with 30 people; and trialled remote and zonal heating controls in 12 homes.

Understanding heating experiences

People want to use heat in very different ways to get clean and comfortable at home

People do very different things to get comfortable when they are at home. Nearly everyone uses heating, but a minority of 5% cannot recollect using any at all on a typical winter day (though they may experience heat indirectly from the sun or their neighbours). Most (83%) combine heating with something else to warm up; put heat in specific places; and stop heat escaping (see Figure 3). They live with different degrees of discomfort before acting and delight in the relief when they do.

Thermal comfort is influenced by radiant heat, air flow and relative humidity, not just air temperature.[7] People find a range of environments comfortable and prefer different ranges depending on how active they are and what they are wearing.

Thermal physiology and personal preference combine to cause interesting **average** differences:

- People prefer warmer environments when less active and a falling body temperature induces sleep;
- Women prefer warmer environments to men;
- The elderly live in warmer lounges and cooler bedrooms than the young (perhaps because age can impair the body's ability to regulate temperature);

However, these averages hide huge differences between the thermal environments different individuals prefer.[8]

People are more likely to shower in the morning and bathe at night though timing varies across households, some prefer one to the other and many shower more in summer than winter. One in six put particular importance on using heat and hot water to clean themselves and their home. Respondents in one survey reported showers lasting from one minute to half an hour.[9]

People with different preferences can move into any home. Therefore, low carbon heating systems should be designed to allow people to get clean and comfortable in diverse ways. There is no single, standard that everyone will want.

Ways to improve low carbon heating

Negative early experiences of low carbon heating systems could harden opposition against them unless they are improved. Almost no one with access to the gas grid has installed a heat pump. They are larger, noisier and more expensive to install than gas boilers. Households with older district heating schemes complained that suppliers were unresponsive, systems had to be turned off for maintenance and fixing problems in one home could cause issues elsewhere. Newer designs can fix these problems in general, though consumers may need protection to ensure prices are fair and complaints are resolved.[10]

The vast majority paid to install central heating since the 1970's despite the disruption, perhaps because it was cleaner, simpler, more convenient and safer than what they had before. It also freed up space they could devote to other things. This implies more households might install low carbon heating if existing problems were solved and solutions augmented their home lives more broadly.

Common problems suggest there are ways to improve upon existing heating solutions. Two thirds of people complain of cold draughts, condensation, damp or mould. Perhaps more surprisingly, two thirds have to act to prevent overheating, even in winter. Adoption of lower carbon solutions might rise further if they addressed these difficulties.

Most are more aware they use heat for thermal comfort than hygiene. Few appreciate how much they value heat to promote health, enrich relationships and protect property (see Figure 3). Some want to put their health first, but do not realise how heat relates to their well-being until they fall ill. Around a third service their heating system to increase their peace of mind that it will work when they need it. Others take heat for granted and miss it only when systems break. Low carbon heating might be adopted more widely if systems helped households create healthier, more harmonious home lives.

[7] Parsons (2002). Human Thermal Environments.

[8] Kräuchi (2007). The human sleep-wake cycle reconsidered from a thermoregulatory point of view. Physiology & Behavior, 90(2-3), 236–45.
Karjalainen (2012). Thermal comfort and gender: a literature review. Indoor Air, 22(2), 96–109.
Kane et al. (2010). Does the age of the residents influence occupant heating practice in UK domestic buildings? East Midlands Universities Association 2010 Conference.
Kenney and Munce (2003). Physiology of Aging Invited Review: Aging and human temperature regulation. Applied Physiology, (18), 2598–2603.
Jacquot et al. (2014) Influence of thermophysiology on thermal behavior: the essentials of categorization. Physiology & Behavior, 128, 180–187.

[9] Pullinger et al. (2013) Patterns of Water.
Myers (2010) Save Water Swindon: Baseline survey summary report. Waterwise report.

[10] Which? (2015) Turning up the heat: Getting a fair deal for District Heating users.

Understanding heating experiences

Continued »

FIGURE 3

The things people use heat for today

People use heat to warm up and cool down

- 23% use hot water bottles
- 36% make a hot drink
- 62% put on warm clothes
- 31% use blankets around the home
- 45% draw curtains and blinds
- 28% open windows during the day
- 18% wear lighter clothing
- 50% turn heating off or down
- 14% open windows at night
- 32% open windows in winter

People use heat to clean themselves and their homes

- Shower to wake up in the morning
- Bathe to wind down at night
- Use hot water for cleaning

Duration varies 1-30 minutes

- 44% open windows to remove smells
- 85% open windows to get fresh air

People use heat to promote health

- 61% consider health a significant factor in how they use heat at home
- 19% report living in households with someone suffering from a heat related health condition*
- 10% Some of the highest 10% of gas consumers use exceptional amounts of heat to relieve pain

* The survey asked if anyone in the household had a physical or mental health condition, injury or illness that affected how warm or cool they liked to keep their home or how much hot water they used.

People use heat to enrich relationships

- 75% Live with others
- 53% Use heat to care for other household members
- 55% Adjust heating to host guests

People use heat to protect property

- 40% stop pipes freezing and prevent damp
- 30% close windows to stop theft (which can cause overheating)

Installations, upgrades and decisions

People put off upgrading their heating system if they can

People delay replacing their heating system if they can. Two thirds complain about heating problems, but only 11% have replaced their system to address them. Half of those who have, waited over three months before they had a new system installed.[11]

People prefer to endure discomfort and inconvenience to avoid investing time, money and effort to get the work done. They say they want to get the most out of their system before changing it but cannot see its limits or how much better a replacement might be.

Interim solutions would allow low carbon heating to displace gas systems more quickly

Most people replace their gas boiler when it breaks (30%) or is about to break (31%). They might consider alternatives in future if they were aware of them and felt they were competitive in terms of price and performance. However, low carbon heating systems may also need additional work in or around a building to work effectively. Heat pumps may need network upgrades to increase the power of the electricity supply and building insulation or draft-proofing to reduce the heat lost. District systems may need a trench to connect to a heat network, where one is available.

There will be situations when people want a new heating system before preparing their building for a low carbon alternative. Today, 39% wait less than 3 months. If they are to realistically consider a low carbon alternative, they may need a rapid, interim solution that can act as a stop-gap until an effective system can be installed. Otherwise they may install a new gas boiler which 89% expect to last more than 9 years.[12]

[11] DECC (2013) Home owners' willingness to take up more efficient heating systems.

[12] DECC (2013) Home owners' willingness to take up more efficient heating systems, p48.

Owners might want to prepare buildings for low carbon heating if it was easy and also improved their properties

There is an opportunity to prepare buildings for heat pumps by installing insulation or draft-proofing when they are renovated. Around a third of households are planning renovations at any time. Half consider improving energy efficiency when the work is done. 85% claim they might spend on average 10% more to incorporate energy efficiency if asked. There is enough time to integrate preparations as 75% of renovations are planned and 70% of plans take over a year to finalise.[13]

More will take this opportunity if they expect preparations to bring other, more immediate benefits as 90% renovate to improve their property. Even the 10% who renovate to enhance energy efficiency want to improve comfort more than reduce running costs. This is why projects encouraging people to install insulation or draft proofing recommend emphasising warmth rather than potential savings. It also helps explain why efficiency measures can save less energy than models predict.[14]

Conversely, people will avoid actions they perceive will make their property less valuable, for instance if insulation reduces space or obscures period features. They prefer to renovate when properties are empty, or phase work to reduce the disruption, even though this is less efficient than doing everything at once.[15] This implies they might be more willing to prepare their home if it reduced the disruption of conducting other work, for instance by speeding it up.

[13] Wilson et al. (2013) Understanding Homeowners' Renovation Decisions
EST (2010) Trigger points: a convenient truth.

[14] Wilson et al. (2013) Understanding Homeowners' Renovation Decisions.
Consumer Focus (2012) What's in it for me.
Hamilton et al. (forthcoming) Energy efficiency uptake and energy savings in English houses: a cohort study.

[15] Mallaband et al. (2012) Barriers to domestic retrofit – learning from past home improvement experiences.
Simpson et al. (2015) Energy-led domestic retrofit: impact of the intervention sequence, Building Research and Information.

Installations, upgrades and decisions

Continued »

It may help to explain benefits sensitively as homes are emotional spaces. Advice on costs, savings and retrofits can undermine how people want to feel in their home: 'advice' restricts people where they want to feel free; 'costs' induce anxiety where people want to unwind; 'save' implies stinginess when people want to appear generous; and 'retrofits' expose problems in places people want to feel safe.[16]

People prefer different benefits depending on whether they view their home as a haven, social space, asset or some combination. Their preferences also change over time: improve appearance (on/before they/someone else arrives); make them more practical (when they learn what they want or their needs change); or upgrade them (to raise sale or rental value).[17]

Ultimately heating plays an invisible, yet integral, supporting role, so more will improve their building's thermal performance when they can see how this will enhance life at home.

Owners need to know what solutions will work in their area so they can prepare their properties effectively

Unfortunately, households struggle to make informed decisions about the thermal details of any renovation. Occupants do not know how insulated their home is, what thermal outcome they want, or how their needs might change.[18] Owners cannot predict what prospective buyers or tenants will value.

Tradespeople play a central role in selecting, installing, setting up and maintaining heating systems. It can be difficult to fix heating systems installed by different people over a sequence of renovations. Those who can deliver solutions that work well in most situations reduce the risk that they are called back by dissatisfied clients. Their caution may mean they recommend systems they know how to install, set them up to provide more than enough heat and hide controls which can prevent settings being altered.[19]

People are faced with an inadequate understanding of this complex problem and conflicting advice. Reputable builders may even resist recommending insulation to avoid appearing to be selling more work.[20] The result is many missed opportunities to prepare buildings for heat pumps when they are renovated.

People will need support if they are to consider thermal details when they renovate. The nature of the gas, electricity and heat networks in their area will also limit what heat technologies will work. Widespread preparations will only start when owners know which solutions will work in their property in future.

[16] Harries (2014) Notions of house and notions of home – their importance for interventions to reduce domestic electricity consumption. Behave conference.

[17] ETI Qualitative research.

[18] Ernst and Young (2011) Green Deal: Trust, education and finance are key to consumer adoption.
DECC (2011) Understanding potential consumer demand for the Green Deal – Data Tables.
DECC (2013) Estimates of Home Insulation Levels in Great Britain.

[19] Wade (2014) Scripted central heating installations and why they matter. Behave conference.

[20] EST (2010) Trigger points: a convenient truth.

Controlling heating and spending

Public concern over bills conceals private confusion: few consider cost in how they use heat at home

Almost everyone agreed that cost was a significant factor in how they used heat at home, that bills were too high and that it was good to minimise waste. However, this public consensus masked private confusion over how energy was used, what this cost and controversy over what waste means.

Whilst all felt it was a **waste to pay for heat that delivered no benefit,** they defined waste and benefit in quite different ways. Around a third (36%) claimed to try to conserve how much energy they used, for instance by turning thermostats down, heating off when they went out and down in rarely used rooms. Another third put more emphasis on ensuring they (9%) or others' (18%) had the heat they wanted, for instance by preheating empty homes to avoid sitting in the cold waiting for them to warm up. The final third (37%) were relatively disinterested in heating altogether.[21]

People struggle to relate what they do to the cost of the heat they use because heat consumption is a by-product of daily life, a coincidence rather than a conscious choice.

Heat can escape from opening windows in winter even if the aim is to get fresh air (85%), let out smoke or smells (44%), get to sleep (38%) or avoid condensation (38%).

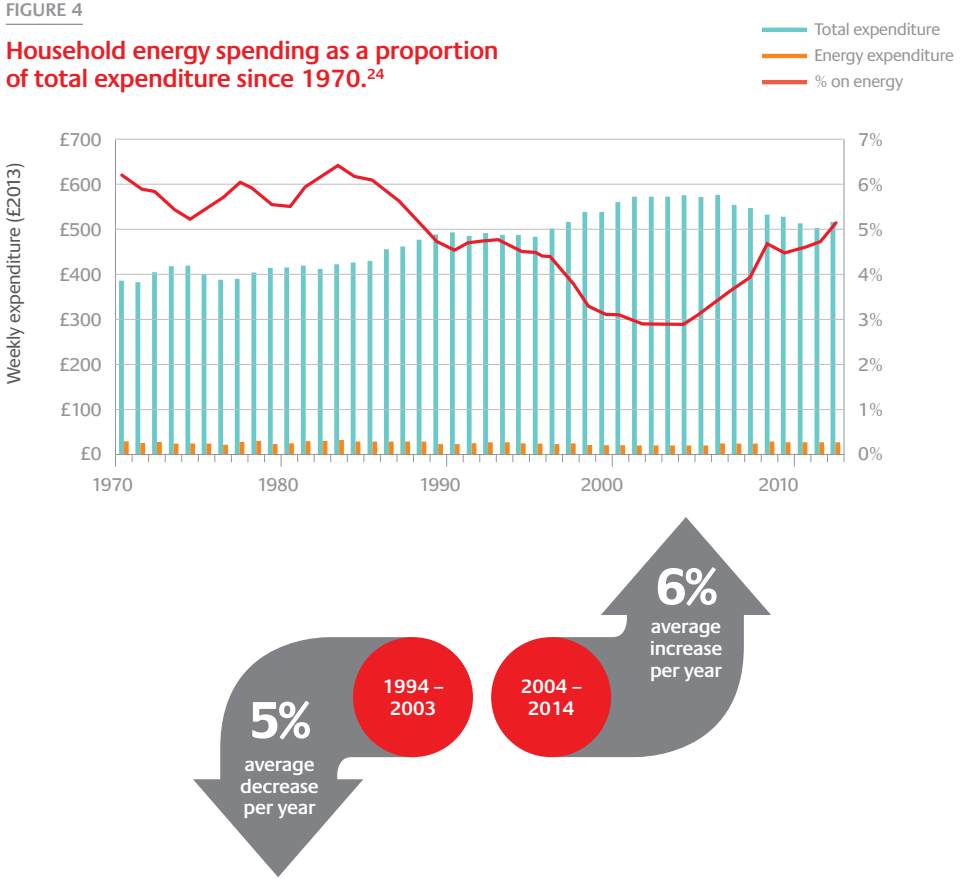
Few realise that on average households use 80% of their energy for heating and hot water costing around £750/year (~£15/week – annual average 2014).[22] Most people say they care more about heating bills than their behaviour implies they really do.

People are frustrated that they cannot control how much they spend (or energy they use) to get clean and feel comfortable at home

People say they are concerned about energy bills. They fear they will not be able to pay for the heat they need in future, even if they can afford what they use today. Their fears are exacerbated because they do not understand why costs are rising (see Figures 4 and 5) or the best way to get comfortable using less.[23]

FIGURE 4

Household energy spending as a proportion of total expenditure since 1970.[24]



[21] It is hard to accurately estimate the prevalence or priority of needs people have but do not report and the priorities people state in a survey are unlikely to predict behaviour. Our year-long study of 30 homes found households frequently used heat in ways they were unaware of but felt were very important on reflection. However, the estimate that around a third are concerned with conserving money or energy does correspond with other relevant statistics:

- Less than 30% have ever switched to save money (Ofgem, 2014 Customer Engagement with the Energy Market).
- 35% reported being fairly or very worried about their energy bill at the time the ETI research was conducted (DECC, 2014 Public Attitudes Tracker: Wave 10).

[22] Fell and King (2012) Domestic energy use study: to understand why comparable households use different amounts of energy.
EST (2014) Pulse study.
ONS Living Costs and Food Survey.
DECC (2014) Annual domestic energy bill estimates.

[23] Butler et al. (2013) Deliberating Energy System Transitions in the UK.

[24] The data for this graph comes from various ONS surveys: Family Expenditure Survey (pre 2001), Expenditure and Food Survey (2001-2007) and the Living Costs and Food Survey (2008 onwards).

Controlling heating and spending

Continued »

FIGURE 5

Controlling heating and spending

~£15 per week

on heating and hot water in 2014 this equated to an annual spend of £750 or ~ £15 per week

80%

On average households use 80% of their energy for home heating and hot water

££ Rising Prices

Might encourage people to try and use less, but could harm those least able to pay

Control

People are frustrated that they cannot control how much they spend making their homes feel comfortable

Heat can escape from opening windows in winter even if the aim is to get fresh air (85%), let out smoke or smells (44%), get to sleep (38%) or avoid condensation (38%).

Controlling heating and spending

Continued »

Whether they plan, react or leave their system alone,[25] they cannot get what they really want. Those who spend lots of time trying to save energy or money often fail to minimise their bill and may risk harming their health or damaging their home. Those who save time by leaving their controls alone often spend more than they would like.

Common confusions surround how best to combine local with central heating and when to turn heating down or off. To explore these we modelled the impact of alternative heating approaches in eight study homes[26]:

- Around 50% report topping up central heating with local heat.[27] The model found that this could increase costs if electric heaters were used instead of gas central heating.
- Around 15% report turning their heating down in rarely or unused rooms to save energy or money. The model found this saved less energy than was normally used to warm the room (as heat arrived from adjacent spaces) and increased the risk of mould.
- Around 10% report leaving their heating on to try and save energy. The model found that this used more heat, but that maintaining a moderate temperature can reduce the risk of mould and warm a home up more quickly.

Whatever their priorities, many struggle to value energy as they do not know the cost of the experiences they enjoy at home.

Households' (socio-technical) situations limit their choices

It is hard for households to choose how to control their heating as they cannot see how their situation constrains their options. Figure 6 explains how the social life of each household, their heating system and thermal character of their home constrains how much time and energy it takes them to get comfortable.[28]

[25] Rubens and Knowles (2013) What people want from their heating controls: a qualitative study.

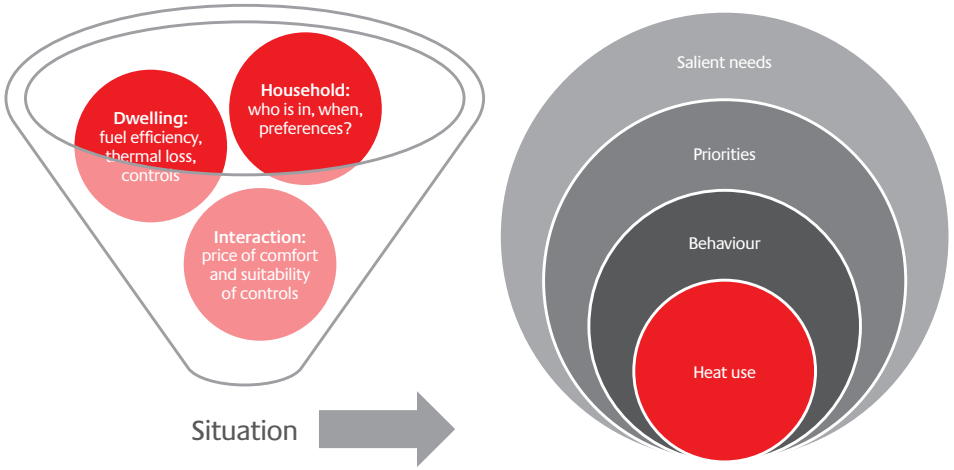
[26] The model showed that:

- Heating the whole home to 19°C from 7-9am and 4-11pm and using an electric heater to warm the lounge to 23°C from 6-11pm increased costs 30% in one case study compared with centrally heating the whole home to 21°C from 7-9am and 4-11pm. Using heat to warm a person rather than a space could save energy.
- Turning down the temperature from 21°C to 18°C in all 4 bedrooms of a 1980s detached house during the day saved 6.25% of the heat used. Turning the heating off in one of three bedrooms in another case study saved half the 11% normally used to heat that room when the door was shut, but only about 10% (i.e. 1.5%) when the door was left open.
- Heating eight homes to 14°C at all times and 21°C between 7-9am and 4-11pm actually used 3.5-11% more heat than allowing temperatures to fall lower than 14°C outside these periods.

FIGURE 6

Situations shape heat use

Interactions between the household and their dwelling create a situation (left) that determines what needs are salient to a household (right). Occupants place different priorities on meeting the needs they realise they have and the way they behave ends up using heat.



People are concerned about their heating bills as they cannot choose how much they spend or see what they get.

[27] Central heating is often referred to as primary heating and other sources as secondary. This paper uses the term local heating instead, to emphasise that portable/fixed electric/gas/biomass heating is local and can be used as the primary source.

[28] Shove (2003) Comfort, cleanliness and convenience: The Social Organization of Normality. Berg Publishers.

Controlling heating and spending

Continued »

Consider the situations of two fictional households. An affluent single man living in a modern, well insulated flat with an efficient combination gas boiler who spends a lot of time out socialising, may not notice his heating very often. Conversely, a retired couple with little disposable income who spend most of their time in their off-grid, detached, solid walled home may notice their heating more frequently.

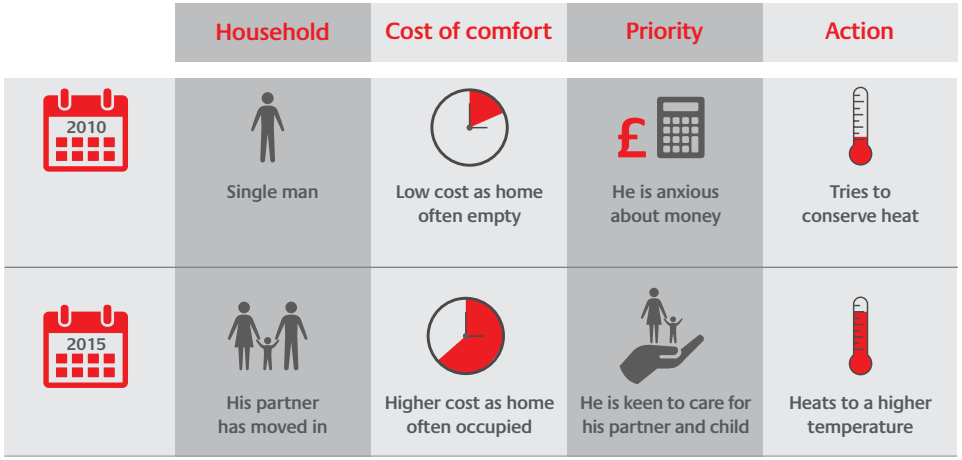
They react to their situations in different ways. The single man is anxious about money so he spends time adjusting his thermostatic radiator valves (TRVs) and doors even though his heating does not cost him very much. Conversely, the retired husband may heat his whole home and water tank at all times because he feels he has earned the right to feel comfortable and shower when he likes whatever it costs.

These situations will change during each day, across seasons and over the years. If the retired husband passed away, his widow might learn how to use her controls, notice her heating costs and try to use less to save money. Conversely, if the single man met a partner who moved into his flat to have their baby, he may want to use more heat to keep his new family comfortable, whatever the cost (see Figure 7). The formerly single man may want to use less heat if he is at home alone and the widow may want to use more to welcome guests.

FIGURE 7

Heating practices can change with the household situation

An example scenario demonstrating how a single man's heat choices change



The social situation limits the carbon any technology will save; the technical situation limits the carbon any behaviour can save. People may use (and heat) more rooms if insulation means they become easier to make comfortable;[29] they can use less energy, but will save limited carbon until they change their heat supply; district heat may emit less carbon than gas boilers, but people can use more energy if it is simpler to cool down by opening their windows than turning their heating off (as can be the case with older schemes).[30]

It is also more informative to consider the range of situations people find themselves in at home rather than the average. The highest 10% of gas consumers in the UK use 3.7 times as much as the lowest 10%. This is because ordinary things, like back pain or a shaded lounge, can cause extraordinarily high heat use. One study of 290 almost identical dwellings found that the highest used twenty times more heating than the lowest.[31]

Events can conspire to make heat less affordable. The arrival of a baby, onset of illness, or entry into retirement can mean people spend more time in warmer homes just as their incomes drop.[32]

Most can adapt what they have to get what they need

Many people find their existing heating controls hard to use.[33] They force people to tell the system what they want in future: when they want heating on, what air temperature or TRV setting they will find comfortable, and (for the 46% with tanks) when to heat up water.[34] This will be easier (and more appealing) for some than others, but life can be unpredictable and people may need to experience a situation to decide how to react.

[29] This may be partly why efficiency measures save less than models predict.

[30] Some participants with district heating in our study reported using windows to cool down because this was simpler than using their controls to prevent overheating.

[31] DECC (2013) Heating gas consumption by property types: NEED table requests.
Fell and King (2012) Domestic energy use study: to understand why comparable households use different amounts of energy.
Andersen (2012) The influence of occupants ' behaviour on energy consumption investigated in 290 identical dwellings and in 35 apartments. Healthy Buildings.

[32] Our model showed that 80% more gas was required to heat a 1980s detached house to 22°C from 7am-8pm every day than to 18°C from 7-8am and 5-9pm on weekdays and from 7-11am and 3-9pm on weekends.

[33] Consumer Focus (2012) Consumer and domestic heating controls: a literature review.

[34] 89% of homes in our survey had a timer and either TRVs or a room thermostat to control their heating; 63% had all three. 86% of people with hot water tanks had a timer.

Controlling heating and spending

Continued »

Most can cope with either feeling uncomfortable, running out of hot water or paying for heat they may not use. This is because gas boilers are powerful enough to recover rapidly and heat up a cold room or tank of water. Local heat is also popular as it is simpler to adjust, easier to direct and faster to respond.

People feel better controls help them benefit more from the heat they buy

Newer controls make it easier for people to adjust their heating times and target temperatures from anywhere over the web. Some use software to predict when people will want their heating on, others allow users to set different zones to try to reach different target temperatures.

This sort of functionality appeals to about two thirds of households. Some, often families, like the idea of having more control over where heat goes, others, more likely to be singles or elderly, like the idea of algorithms that make control more convenient but are sceptical technologies will work.

Participants in our small-scale trials enjoyed the new remote and zonal functionality they tried out. They felt they were benefiting more from the heat they bought. Remote control made it easier to adjust their heating, even from the sofa or without getting out of bed. They used it to pre-heat homes (particularly if they took a long time to warm up); remotely turn heating off; amend schedules; and make others comfortable. They were more likely to correct settings when they realised they were not as they wanted, rather than having to try to remember when their wall-mounted controls were next within reach. They thought setting radiators to different targets at different times enabled them to reduce waste and keep more people comfortable (although average internal temperatures were unaffected, perhaps because doors were left open).

Some were annoyed by algorithms that misunderstood what they wanted. Others found it confusing to set a time to reach a temperature and disliked losing control over when the boiler came on. These early frustrations hint at how to improve usability or introduce useful new functionality.

Heat pumps may need more advanced controls

However, it can be hard for electric heat pumps to quickly warm a cold house or heat enough hot water for a bath or shower. This is because the costs rise far faster with the power of the system than it does for gas boilers.[35] There are two affordable alternatives, both need more advanced controls.

One design combines low power heat pumps that take longer to heat space up, with insulation so it cools down more slowly. The other, hybrid systems, can use a gas boiler to provide faster heating. Both can pre-heat water and store it in a tank to use later on.

Very few people have experiences of heat pumps. Early adopters can find them hard to control. They may consider it wasteful to leave systems on at all times and frustrating to wait for heat or hot water they had not planned to use. They use local or immersion heating on occasion to recover,[36] but would value improved control.

More advanced controls are a key component to unlocking deeper decarbonisation

Decarbonising heat may change the structure of bills as a low carbon energy system will cost more to build and less to run.[37] People powering heat pumps with low carbon electricity need not spend much more (or emit more CO_2) to use more heat. However, the cost of their electricity could vary during the day.[38]

People could reduce their bills by scheduling their heating to times when the costs were low and storing it to use later on.[39] However, they might find it hard to decide when to heat up a room so it was warm when they wanted (or when to heat a tank of water so they could take a shower when they liked). Advanced controls should help people plan their heating.[40]

Delivering this assistance requires estimates of how long it takes to heat up a room (or water tank) or cool it down. Advanced controls could help people use these estimates to decide whether it was worth preparing their property for a low carbon heating system during renovations.

[35] The costs include the price of a more powerful heat pump and increasing the power of the electricity supply to the house (both the cost of the supply cable and the peak generation capacity).

[36] EST (2014a) EST heat pump field trials – phase 2 consumer research report.

[37] ETI (2015) Options, choices, actions: UK scenarios for a low carbon energy system transition.

[38] Wholesale electricity prices could vary more often and more dramatically with the time of day, costing less when there is more supply than demand.

[39] They might value storing heat in a water tank or insulated building as it increases the delay between paying for energy and enjoying heat.

[40] They should help people predict when they want heat and decide how to buy heat for events that they cannot.

Summary, conclusions and next steps

Less than 4% have low carbon heating, like heat networks or heat pumps, though they have been available since the 1970s. In contrast, the vast majority paid to install central heating, despite the disruption, as it was better than what they had. There are three key challenges to solve if the UK is to meet its carbon targets at minimum cost by decarbonising heating.

80%

Widespread public concern about energy bills conceals low awareness that households use, on average, 80% of their energy for heat and hot water. This costs around £15 per week.

1) Improve low carbon heating experiences

More people will want to adopt lower carbon heating systems that they perceive to offer advantages over what they have. Designs could be improved by fixing flaws with existing systems or enhancing peoples' experiences of heat at home. Success will come from appreciating everything that influences thermal perception and recalling that people also value heat to enhance their health, enrich their relationships and protect their property.

The ETI will work with industry to seek to improve the design of electric heating systems. There is also a need to improve understanding of what constitutes a healthy, comfortable home environment.

2) Make low carbon heating simple to prepare for and install

Most people avoid upgrading their heating systems if they can, and replace them with another gas boiler when they have to. Few will consider an alternative, even if performance and cost were comparable, unless it was also convenient to install.

Many properties will need to be prepared to make low carbon heating systems a viable alternative to gas boilers. People will be more motivated to prepare for the future in ways that they expect to deliver more immediate benefits. Measures should be designed to fit well alongside home improvements. Installers will need assistance if they are to prepare homes effectively.

There will be situations when people want a new heating system before they have prepared their property. Interim solutions may be required unless low carbon heating systems can be installed within a comparable timescale to a gas boiler.

3) Make heating easy to control

Widespread public concern about energy bills conceals low awareness that households use, on average, 80% of their energy for heat and hot water and that this costs around ~£15/week (annual average in 2014).

The ETI will seek to improve the design of heating controls so people can get the most out of their heating and better prepare for low carbon heating systems. The aim is to ensure people can get what they want from heat pumps and understand the thermal implications of alternative renovation decisions so they can prepare their home effectively.

In addressing these three challenges, it is also important to remember that there are vulnerable households for whom access to heat is a problem. Further work is needed to understand the behaviours and motivations of vulnerable households, so that low carbon solutions work for people who may be in fuel poverty.

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Appendix

This section describes the ETI studies that underpin this report.

A consortium of Frontier Economics, Hitachi, NatCen, Peabody, PRP, TTP, University College London delivered the following:

1) Literature review of ~350 papers on domestic heat use and responses to smart energy systems.
2) Analysis of political, economic, social, technological, legal and environmental factors that may change domestic heat use.
3) Three phases of qualitative research encompassing:

   a) 38 group discussions with 153 participants in York, Manchester, Norwich and London;

   b) Longitudinal study interviewing 30 of these 153 participants four times over a year to understand the impact of life changes, and using sensors to see beyond what they said to understand what they did;

   c) Interviews with an additional 33 households living with insulation, heat pumps or district heat.
4) A model exploring the impact of changing building fabric or heating schedules on energy demand in eight of the 30 homes in 3b above, using the US Department of Energy's EnergyPlus.
5) An in-home survey of how heat practices varied in a representative sample of 2,313 GB households.
6) Focus group discussions to develop and gather feedback on early solution concepts with 30 participants.

New Experiences conducted a small-scale field trial of either zonal or remote heating controls in a total of 12 homes.

Loughborough University reviewed ~150 papers on thermal comfort and conducted additional supporting statistical analysis of the in-home survey data (in 5 above).

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