National Energy Study

SUSTAINABLE HOMES

National Energy Study 2

SAP IN THE REAL WORLD: HOW PEOPLE USE ENERGY IN THE HOME

IT IS SOMETIMES EASY TO THINK OF CLIMATE CHANGE AS BEING ABSTRACT, THE PROVINCE OF GLOBAL LEADERS, SUMMITS AND THINK TANKS. BUT TACKLING THIS MASSIVE CHALLENGE REQUIRES US TO ACT ON ALL FRONTS AND ON ALL SCALES – NOT LEAST IN THE UK'S 27 MILLION HOMES.

Tackling the problem of reducing domestic energy use is a huge and complex task. It is all too often dominated by the single issue of fuel poverty – but the truth is that, in reality, fuel poverty is only a small part of the problem. We know a great deal about how energy is used, and how it is possible to cut down this use. But we understand much less about what motivates people so they take action to reduce their energy demands.

If we view the task of reducing energy consumption as being purely based on cost we are missing a trick.

It might appear that motivating people to cut their fuel bills is the most obvious solution. What better motivator could we hope for? It is certainly more immediate and more personal than the distant notions that we ought to be producing less carbon dioxide and reducing climate change; it also avoids the scientific terms that make some people's eyes glaze over.

But as previous studies have found, money is not always the best motivator. People are more likely to change long-standing habits if they know others are using less, or if they receive feedback which helps them to feel good about themselves.

Programmes of improvements for housing stock are often led by SAP (the Standard Assessment Procedure, used to assess the energy rating of homes). As this is directed at buildings rather than their users, some significant issues can be missed, such as hot water use, draughts and residents' understanding of their heating controls.

As we push for new and existing homes to be more energy efficient it's important that we understand the complex motivations behind energy use and behaviour change. As this research demonstrates, the SAP value of a home is not always a good guide to its energy use. If we are to win the battle for energy efficiency, we need to understand how people actually behave in their homes – and the reasons behind it. Only by doing so can we ensure that the potential of this major contribution to fighting both climate change and fuel poverty is fully realised.

LORD DEBEN
CHAIRMAN, COMMITTEE
ON CLIMATE CHANGE

What do we know about how people think of energy?

This is Sustainable Homes' second National Energy Study, undertaken with data from 520 homes from 13 housing associations during the first six months of 2015. It builds on the findings of the first study a year earlier.

In the first study we looked primarily at behavioural motivators in saving energy, with our findings suggesting that:

- Homes with higher SAP values were not reducing residents energy costs as much as might be anticipated
- Some residents who experienced difficulties with their bills were not necessarily those on the lowest incomes;
- Even on the lowest incomes, more than half did not consider themselves to be having difficulty with bills.
- The lowest income groups and also those experiencing the most difficulties were spending more on their energy than others.
- Those who displayed the least understanding of their heating systems tended to be the highest users.
- Housing associations are the most trusted source of advice for their residents on helping them to achieve energy savings.

This report looks at some of the key findings from the second National Energy Study (NES2), but a more in-depth report due in January 2016 will delve into the full results in detail.

It is clear that our energy use is considerably more deeply ingrained than a simple financial expense, for many reasons:

- **People don't set out to use energy.** It just happens to be expended in everything we do. If we bake a cake, or drive to the next town, then we only use as much energy as we need to do this. We don't consider ourselves to be wasteful, we are just living our lives.
- **"It's my home, why can't I be warm in it?"** A person's comfort level, and the degree to which they aim to provide comfort and protection for their families is a much greater concern to them than the financial cost of achieving this. Feelings of warmth are closely linked with feelings of security, and for this reason people can be quite protective against being told how warm they should have their homes. The common advice 'turn your thermostat down by one degree' has become ineffective, because people just turn it up again.
- **"I only use as much energy as I need to"** For a person to recognise where savings can be made, there needs to be some understanding of a) what is normal usage, and b) which appliances are the most significant energy users. In order to do that, measurement of energy needs to be better understood.
- **"I can't understand my energy bill"** The standard unit of energy use is the kilowatt-hour (kWh), and while an energy bill contains all the information needed to interpret their energy use, a significant majority have difficulties with this. To many people a kWh is not a tangible unit, and the unit that is much better understood is the £ sign in the bottom right hand corner.
- **"It's not the energy bill I can't afford, it's the double glazing"** True. If double glazing will save £200 per year, but costs £4000 to install, then one isn't saving money any more – not for 20 years, anyway. So the cost arguments for saving energy don't always stack up, and other motivators need to be found.
- **Behaviour change is rarely cost-driven.** Habits almost always override finances. People who have addictions to smoking, alcohol, gambling or shopping continue with these addictions despite increases in price. There may be some awareness that their finances would improve if they abandoned these practices, or even cut down – but the practices are so ingrained that even cutting down can prove difficult.

However, habits are not limited to harmful addictions, and while one might aspire to having lower energy bills, a unit of electricity is, in itself, not cost-prohibitive. If five hours of television costs just 15 pence, then even with a few cups of tea and a hot meal, that is still a cheap evening in. The home heating system tends to incur more expense, but either:

- if the resident knows how to control it, this is normally done with comfort, rather than cost in mind. Or;
- the system is automated using a thermostat and timer and so the home heating 'just happens' without the resident having given a thought to the cost.

Changes to established behaviour need different motivators. We act with regard to people or issues that we care for. Money is given to charities, time is donated to good causes, some people may fast for a period of time for religious reasons, in other words acting for the greater good, or 'intrinsic' reasons.

On the other hand, New Year resolutions, which are normally driven out of self-interest (or 'extrinsic' reasons) – rarely last beyond the end of January. Aspirations to cut down on energy use – to watch less TV, have fewer cups of tea, shorter showers – are more likely to succeed out of a 'charitable' desire to protect the environment than purely on cost grounds. This is because modern living is designed for us to have what we want, when we want, and our comfort levels have become accustomed to this.

What did we do?

This study requested detailed asset management information on homes, and Energy Performance Certificates (where available) in order to break down the measures that were likely to reap the greatest energy savings. 520 two-bedroom homes were recruited from thirteen social landlords around England.

Meter readings were taken over six months, obtaining summer readings too, in order to establish year-round energy habits and estimate hot water use. Residents were also asked a range of questions, covering demographics, occupancy, how well they understood their bills and heating controls. We also probed attitudes to climate change, whether they considered their home was hard to heat or had draughts and which energy-saving behaviours they already practised.

The distribution of participating homes across the country can be seen in Figure 1.

FIGURE 1 – Geographical spread of participants

Data was gathered in the following ways:

- Initial brief questionnaire
- Monthly meter readings (gas and electricity) made on seven occasions (December to June)
- Asset management data obtained from housing associations
- EPCs (energy performance certificates)
- A second, much more in-depth questionnaire at the end of the study
- Qualitative evidence from energy doctor visits made to 40 homes

FIGURE 2 - Timeline of meter readings

READING 1 December 2014	READING 2 January 2015	READING 3 February 2015	READING 4 March 2015	READING 5 April 2015	READING 6 May 2015	READING 7 June 2015
PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4	PERIOD 5	PERIOD 6	

Weather data

Degree days

Degree days (DD) are a measure of how much a building's heating system needs to be used. This is weather data that gives an indication of how much the local temperature falls below a certain point.

We used 37 weather stations across the country, and a standard temperature of 15.5°C, (usual for this kind of study). For every degree that the average temperature falls below this point, one DD is recorded. So if the average temperature is 10.0°C over 24 hours, 5.5 DD is recorded. As degree days increase, heating demand increases in a similar proportion.

The demand for heating in a home closely follows the outside weather conditions. In this study we obtained weather data from 37 weather stations in order to tie in every pair of meter readings with the local weather at that location.

Figure 3 displays that the weather in the locations we studied was very similar to the 10-year averages although homes in the South West appear to use less gas relative to the weather, compared with other regions. All regions averaged at similar levels of electricity use, a national average of 7.9kWh per day, comparable with two-bedroomed homes nationally (see Figure 4).

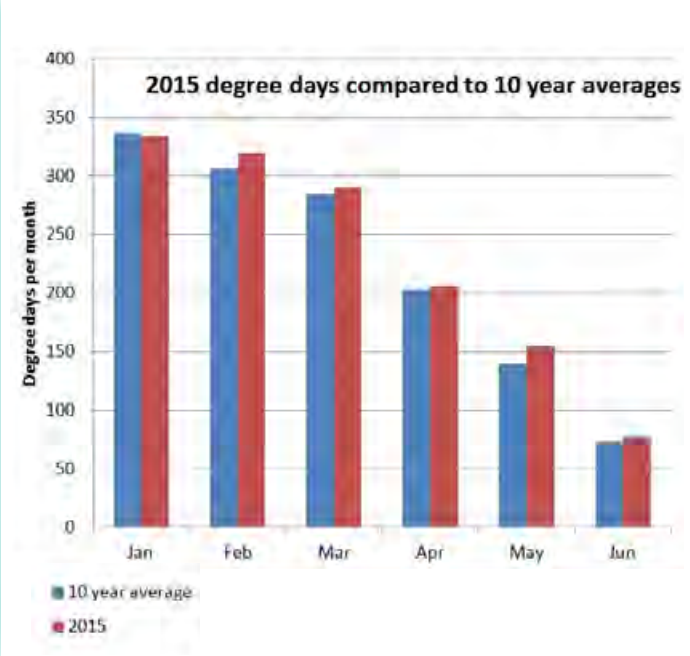

FIGURE 3 – 2015 monthly degree days compared with 10-year averages (data from vesma.com and degreedays.net)

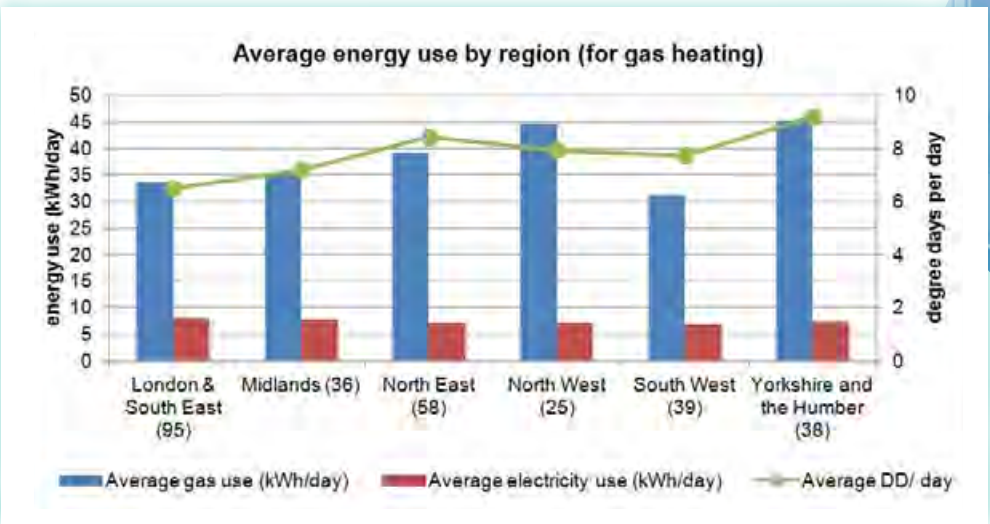

FIGURE 4 – Energy use by region

How our data compares with national characteristics

Figure 5 displays how much energy is used by homes with different income levels, obtained from national data (DECC, 2013). This reflects that as a household's income increases, homes are likely to be larger, or detached, which has a bearing on the energy used there. All the homes in this study were two-bedroomed, although they included all types of dwelling including flats, maisonettes, houses and bungalows. Even so, gas consumption among homes in our study was considerably lower than the national average, at around 7,800kWh per year (equating to an annual gas bill of £413) compared with a national average of 12,500kWh/year (£592).

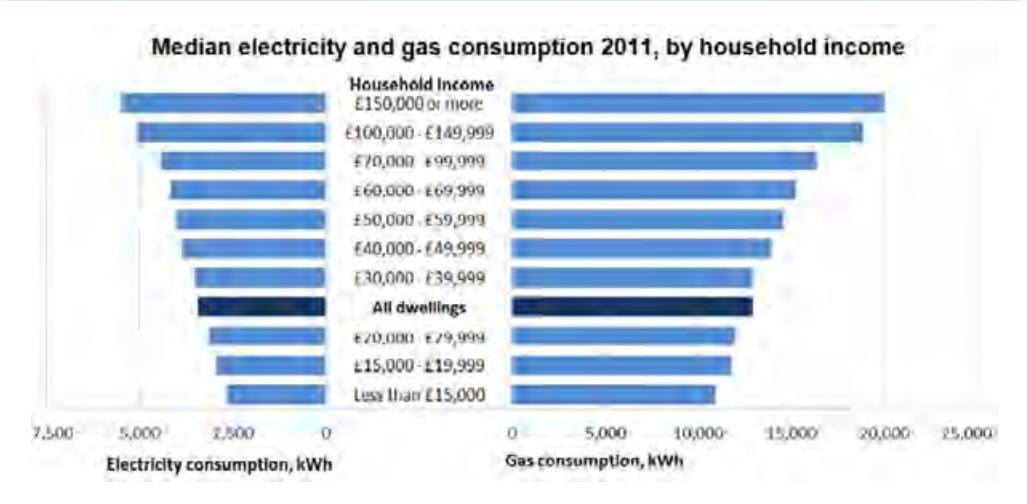

FIGURE 5 – England & Wales annual energy consumption by household income (DECC,2013)

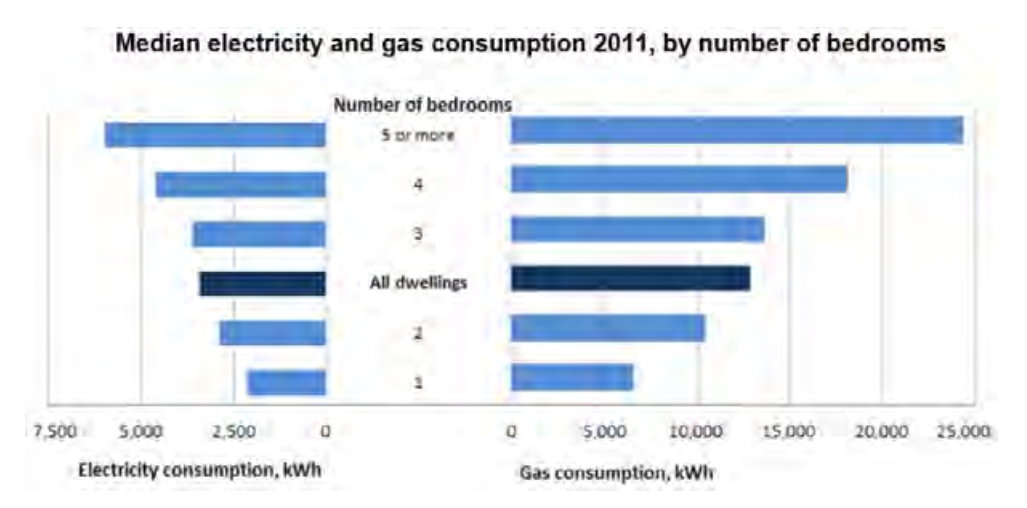

FIGURE 6 – England & Wales annual energy consumption by number of bedrooms (2011) – from DECC (2013)

EPCs and SAP

An Energy Performance Certificate is a home rating required by law to be made available whenever a home is sold or let. It takes into account the age and construction of a home, and includes any factors that affect its energy use, for example its size, the level of insulation, type of glazing and heating systems.

It is intended as a comparison of energy efficiency between homes to inform the purchaser (or new tenant). A rating of A to G is given based on SAP scores on a scale of 1 to 120, where 100 is zero-carbon. The number of occupants N is calculated from an algorithm based on total floor area (TFA), and based on this, an estimate of a typical annual spend of energy is given, which may be used as a comparison for the prospective buyer or tenant.

New homes have a full assessment using SAP, but in an existing building much of the detailed information is difficult to obtain, such as details of the construction materials, and a reduced-data SAP (RdSAP) is used. This method isn't able to calculate how draughty a building is, although some assumptions are built in to the software based on the age of the building.

What did we find?

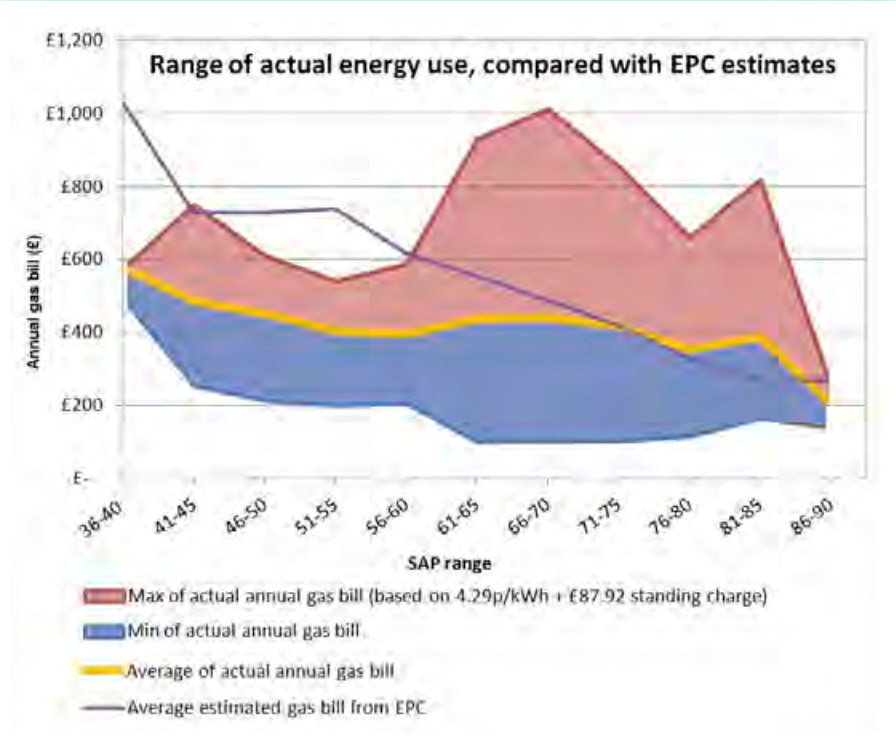

FIGURE 7 – Comparison of actual gas bills to EPC estimates

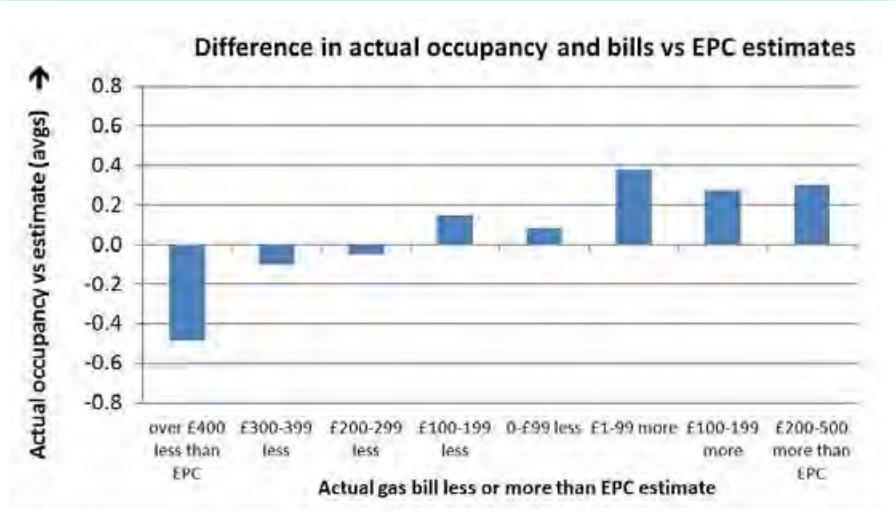

FIGURE 8 – Variation in actual occupancy as compared to RdSAP estimate

Figure 7 shows the average gas bills of participants in our study, compared with the figure predicted for their home by their EPC. Each EPC is calculated based on characteristics of the home, but does not (and is not supposed to) take into account the actual number of occupants or whether or not a home is draughty. The EPC is based on a home being heated to guide temperatures, e.g, 21°C for living rooms and 15-18°C for the rest of the home. This shows that homes with lower SAP tend to be underheated (note that our sample of homes have an income significantly lower than the national average so this may be a factor here). The chart also shows the range to which actual bills vary either side of this average.

The highest users

Of key interest to landlords and those interested in fuel poverty are the highest users of energy. Figure 7 showed the range of energy use compared with what was expected, and the most obvious reason for higher energy use is that more people may be living there. As expected, Figure 8 shows those homes paying considerably more than their EPC estimate had higher occupancy than the 'normal' occupancy according to SAP, though this does not cover all of the discrepancy: the difference in bills was hundreds of pounds while the average difference in occupancy was marginal, indicating that other factors are at play.

Only one home in the study was classified as being in Band F, and while gas bills here were high, they were also much lower than the EPC estimate. That there was only one home in this band points to the good work social housing landlords do to raise the standard of their housing stock – Government figures show that 31% of residents in Band G are classified as fuel poor, compared to only 2% of residents in Bands A-C (DECC, 2015). We have chosen three of the key findings to highlight:

1. THE IMPACT OF DRAUGHTS IS SIGNIFICANT, BUT IS NOT PICKED UP BY SAP

One of the most important factors that EPCs cannot take into account is the effect of draughts. Draughts are a major problem, and particularly so for the elderly. A draught wicks heat away from the body causing it to cool. Falling asleep in a draught is a significant hazard for the very young and the very old as it lowers resistance to infections.

There is also a perception issue. Moving air gives the impression of a room being cooler even though the actual room temperature may not be lowered much. A resident may turn up the heating to combat this – but this wastes heat in two ways: Firstly, the rate of heat loss from the building rises as temperature increases. Secondly, the draught replaces heated air with colder air, causing greater heat loss and higher bills.

The RdSAP assessment which leads to an EPC isn't able to measure draughts, and so assumptions are made about air changes per hour (ach) which are based on other building characteristics, including its age. It isn't possible for SAP to accurately measure ill-fitting doors and windows, or draughts from floors and lofts.

As a result of draughts residents in low-SAP homes behave differently to residents in high-SAP homes. Residents in hard-to-heat homes will often spend cold winter evenings in one room and heat that as effectively as they can – keeping the door closed and drawing curtains. The rest of the dwelling is therefore likely to be cooler than the design temperature for much of the time. Many residents add clothes rather than keep the heating high.

But in higher-SAP homes, residents do not need to take so many precautions to keep the home warm. There are fewer draughts, and so the living room door may be kept open more, enabling warmth to spread to the rest of the house. This means that it is closer to its design temperature, and it becomes less necessary to put on extra clothes. As a result, homes that have been retrofitted to make them warmer for the resident do not always result in large bill savings.

While Figure 9 does show much less draughtiness for higher-SAP homes, one might equally ask why any SAP 81-91 homes should be perceived as draughty. Newer homes built to air-tightness standards ought to eliminate any perception of draughts.

In order to enable proper ventilation of open fires, and also to limit condensation, older homes were not built to be completely airtight. Wooden doors and windows expand and contract in dry and damp seasons, and so natural ventilation removes warm air and replaces it with cooler air that then requires reheating.

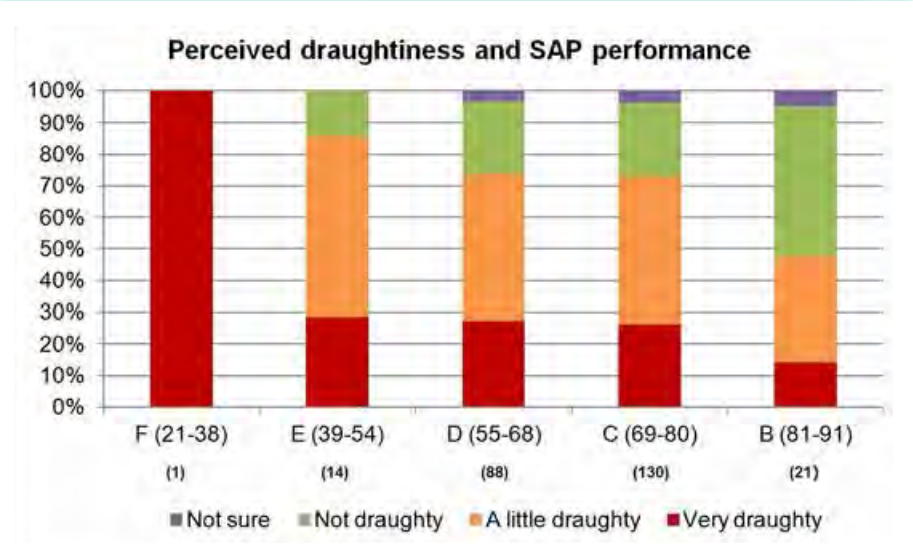

FIGURE 9 – Reported draughtiness according to SAP banding

> *"... the draught replaces heated air with colder air, causing greater heat loss and higher bills.*

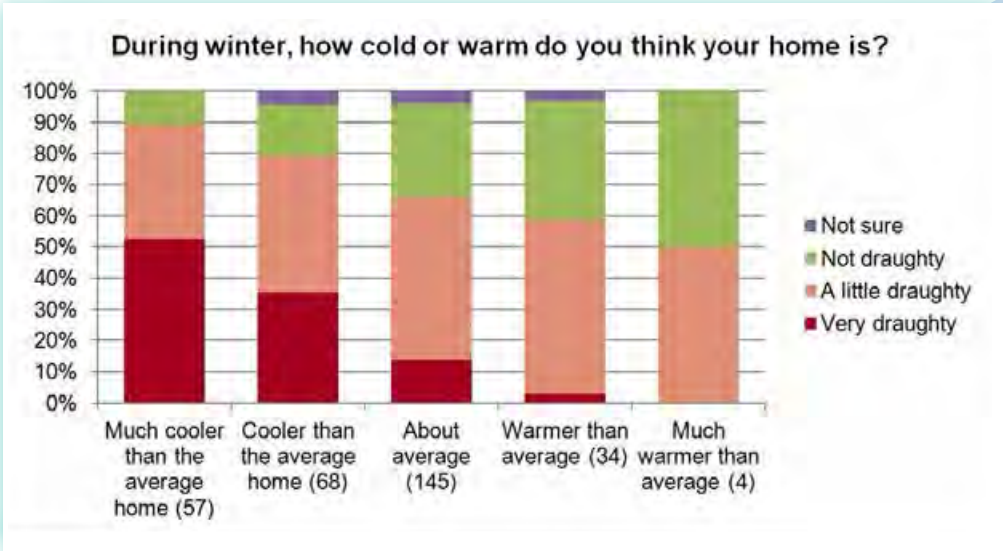

FIGURE 10 – Perception of draughts with coolness/warmth of home

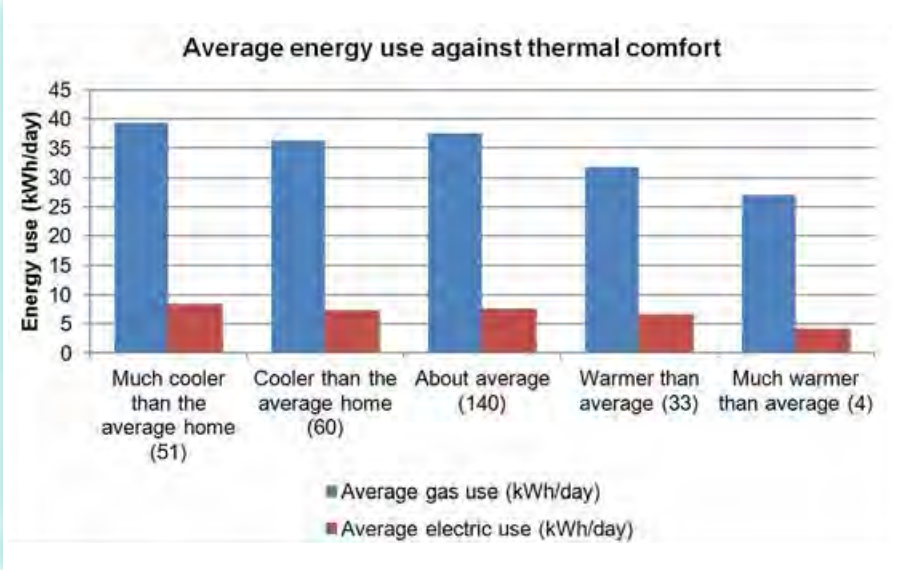

FIGURE 11 – Perception of coolness, against measured energy use

Figures 10 and 11, taken together show the effects that draughts have on a home's energy use. Tackling draughty homes is one of the single most effective ways of improving comfort, and cutting energy use.

Nevertheless, doing so is not without problems, since reducing ventilation within the home can lead to other problems, such as excessive moisture and condensation and, in some cases, growth of black mould which can impact on the health of the residents. So ventilation needs to be controlled, rather than completely restricted.

2. PEOPLE'S USE OF HOT WATER CAN BE SIGNIFICANTLY HIGHER THAN SAP ESTIMATES

It is known that water use varies enormously from one home to the next, and this study attempted to measure this using an assumption that in the summer, space heating would be used little, or not at all. The presumption was that summer gas use could be used to estimate how much hot water may be used at other times of the year.

An alternative solution might be to install water meters into the hot water system, but the former method was chosen on the basis of cost.

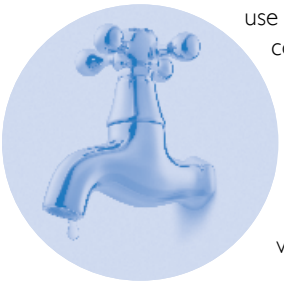

Figure 12 shows how much gas was being used during the month of June (when space heating might be assumed to be switched off), taking into account the expected and actual sizes of the energy bill in that home.

As a guide, 6kWh is roughly equivalent to two hot baths, so in terms of this chart, the highest users appear to be using 9 baths per day, or else keep their heating on in summer months. Other data showed that the same homes showed a similar pattern of use through the winter too. The amount of hot water used in a home depends on the number of occupants, and SAP assumes that they use a little more hot water in winter than in summer. These findings seem to show that the water use is fairly moderate in around half of the homes, but 10 to 20 per cent use significantly more than might be considered reasonable.

The precise reasons will vary from home to home, and individual solutions found for them. Conversations with residents found sometimes water was being heated continuously, or to a very high temperature, or they had a particularly high need for bathing. A common finding is that the switch for the immersion heater is simply marked 'Hot Water'. Without more specific information, residents sometimes leave this on continuously leading to unnecessarily high electricity use.

Our calculations for water use averaged at approximately 40% higher than the total water estimated by SAP, and this worked out that water heating formed 33% of the total gas bill. Even so, because of the very wide variance in the figures we obtained, we have to assume that the highest users were still using their central heating in June.

Whatever the reason, identifying these homes and helping them to address these issues needs to take some priority. We asked if residents understood their heating controls and found that around a third stated they were unsure, or did not understand them Figure 13. Of the majority, it is not fully clear what they understood – some people's understanding is that turning the thermostat to maximum will turn the heating on, which is not an efficient way to operate the system.

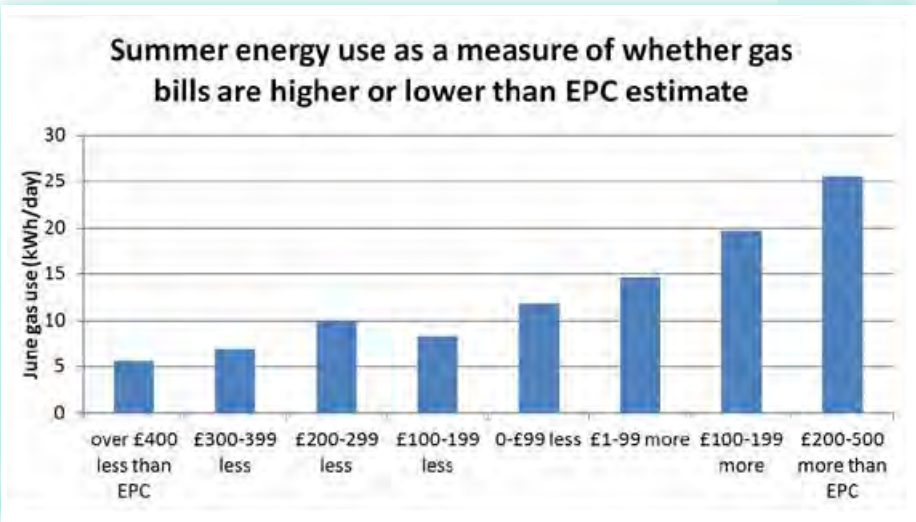

FIGURE 12 – Summer gas use as a measure of whether gas bills are higher or lower than estimated by EPC

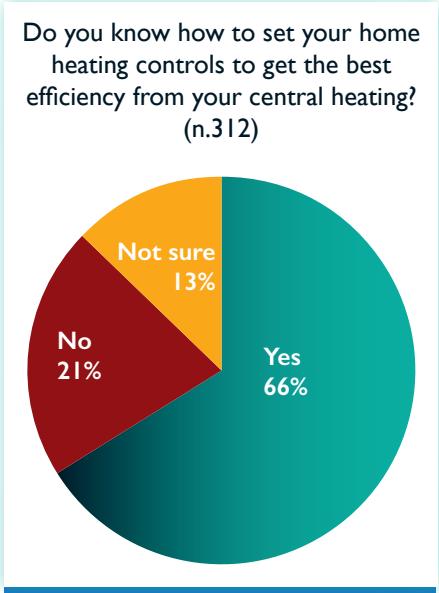

FIGURE 13 – Understanding of heating controls

3. A COMBI BOILER MAY NOT BE THE MOST EFFICIENT SOLUTION, EVEN IN SMALLER HOMES

Replacing the central heating system in a home is a significant expense for landlords. Led by legislation, more efficient condensing boilers are being fitted, and 95% of gas-fuelled homes in this study now had condensing boilers. For statistical reasons, the non-condensing boilers are removed from the following charts.

Considerable asset data was gathered from participating landlords on the characteristics of each home, which has helped us to examine some of the reasons behind high energy use, and those measures that help to address this. Within the study 71% of the homes with gas central heating were fitted with combination boilers

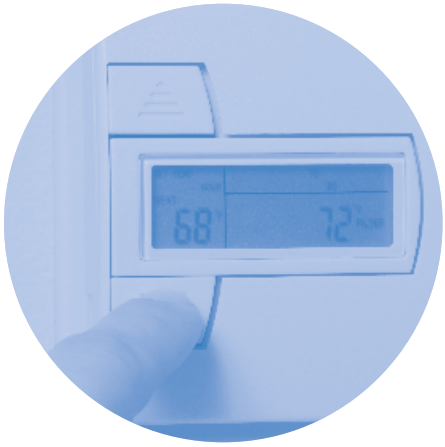

TABLE 1 – Gas used by combi boilers vs system boilers

Type of boiler	Number of occupants	Number of homes	Average gas used (kWh/yr)	Average of SAP
Condensing Combi	1	27	6003	68
	2	52	8757	67
	3	30	8334	65
	4	9	7804	71
Total		118	7947	68
Condensing System	1	10	5868	68
	2	15	7307	74
	3	9	8805	75
	4	6	5832	75
	5	2	6493	69
Total		42	7036	70

Combination and System boilers

Both types of boiler will operate the central heating and hot water systems in a home. The difference is in how they heat the hot water. A system boiler uses a hot water cylinder to store water ready for use, while a combination ('combi') boiler heats water direct from the mains, whenever a hot tap is turned on. This means that no cylinder is needed.

Having no cylinder means that only the hot water that will be used is heated, and the theory is that this means less wastage of heat due to storage losses. There are added advantages of increased cupboard space where the cylinder once was, and it removes the small risk of providing a habitat for the legionella bacteria.

It is generally believed that combi boilers are most efficient for small households that don't use very much water, though they are increasingly being installed in larger homes too.

Evidence from this study suggests that homes with combi boilers actually use 13% more energy than homes with system boilers, even in homes with low occupancy.

There are clear reasons why this might be:

- Hot water cylinders are now increasingly well-lagged, so heat losses from storing the water are much reduced.
- To heat water instantaneously requires a greater thermal capacity (e.g. a 28kW combi boiler might replace an 15kW system boiler).
- The efficiency of a boiler is significantly reduced by being turned off and on, known as 'cycling', because exhaust gases need to be purged after each firing. This energy wastage is known as 'combi loss'. SAP measurements take account of this, though there is a perception that it is a lesser concern than storage losses from a cylinder.
- Some combi boilers have a 'keep hot' facility, which is in effect a small hot water tank within the boiler. A little extra fuel is required to keep this to temperature, however it is normally optional.

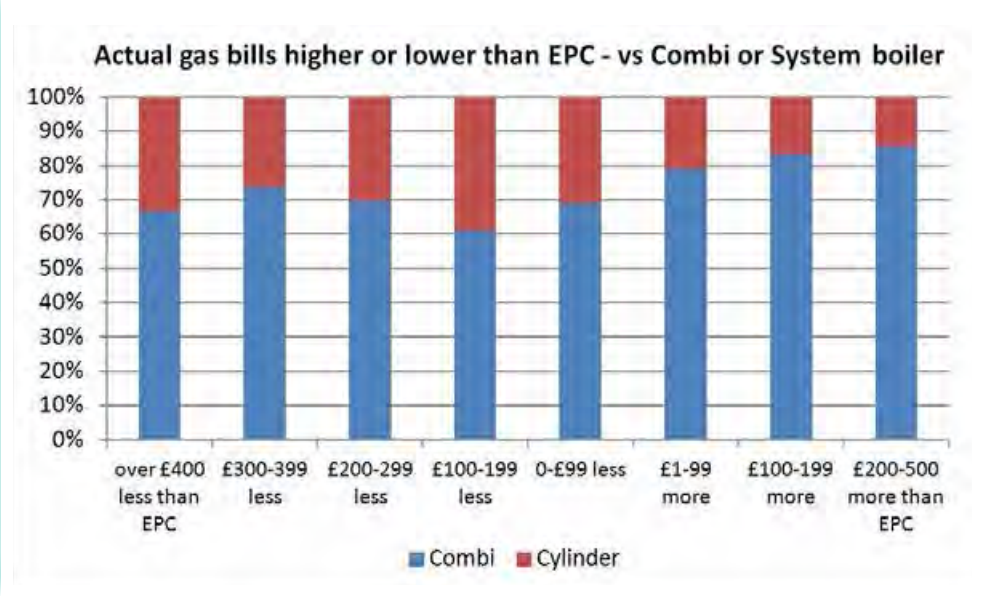

FIGURE 14 – Homes with higher or lower energy use than EPC, according to whether combination or system boilers were fitted

With either boiler, any water in pipes that has cooled must run through before hot water arrives at the tap, however a system boiler will normally wait until the cylinder has cooled around 8°C before refiring, and will then run steadily until the required temperature is reached, keeping cycling to a minimum. With a combi, the boiler is fired up every time, so that if the tap is turned off again before the hot water has run through, this results in zero efficiency.

Figure 14 examines this more closely and suggests that the efficiency of a combination boiler may be overestimated within the EPC, since homes that used more gas than the EPC estimate were 20 per cent more likely to be fitted with a combination boiler, than those who used less than their EPC estimate.

What does this study mean?

Landlords need to know about residents who either have unaffordable energy bills or are underheating their homes and putting their health at risk. Since there are so many different factors at play, it can be difficult to recognise if a home's energy use is out of the ordinary.

It remains the case that one of the best tools in the box to account for these different variations is the SAP rating, either using asset management data or an EPC. This measure is designed as a means of comparing the energy properties of homes for sale or rent, by quantifying all the different energy-related factors, and the result is a predicted energy demand based on assumptions and averages.

This study measured how residents in lower-SAP, more draughty properties frequently heat only the rooms they are using, and therefore for most homes the energy use was much lower than that anticipated by the EPC. Works to improve insulation should make a home easier to heat. But instead of cutting their bills, many residents will respond by heating to a more comfortable level, so their energy use may not necessarily be reduced. This is a phenomenon known as 'comfort take'.

It bears repeating that most people consider themselves to be using only the energy they need – even if there is actually significant energy wastage in their homes.

So the most significant ways that a landlord can help residents control their energy use are:

- **identify which residents need energy advice that is tailored to them;**
- **help residents to better manage their hot water.**
- **educate residents on the best ways to use their heating controls, and to know which are the highest users of energy.**
- **Pay more attention to combating heat loss as a result of draughts**

In this study, homes that residents thought were draughty were found to be using as much as 45% more gas in winter months than homes that were not. Within SAP, a home with double glazing is generally considered draught-free, so where a draught still exists, a resident may have some difficulty making a case for this to be resolved.

There are some cheap and effective ways for landlords to tackle some sources of draughts. Others, such as new doors and windows, are more costly solutions. But there is some grit in the oyster: recent research has found a higher incidence of asthma and condensation leading to black mould, in homes where airflow is reduced. So works that prevent draughts therefore need also to consider adequate ventilation.

This study set out to estimate hot water use by making measurements of total gas (or night-rate electricity) during the summer. The assumption here was that if homes had turned off their space heating systems for the summer, then measurements taken in the summer would give an estimate of the hot water used by their occupants.

The data showed that some homes were using more gas in the summer than the lowest users used in the winter, suggesting that hot water use was unusually high, or that they had not turned off their heating in the summer months.

These homes may not necessarily be using enormous quantities of water, though some conversations with residents indicated that they may be heating it to too high a temperature, or having their hot water cylinder kept hot continuously, or keeping radiators on unnecessarily.

A third of residents stated they did not understand their heating controls, and a challenge facing landlords is identifying those homes where energy use is unusually high, and helping these residents with energy advice to rectify this.

It has become common practice for housing associations to install combi boilers in recent years as an energy efficiency measure, but this study showed that homes with these boilers were using 13 per cent more energy than homes with standard boilers and hot water cylinders. Another reason for RSLs to switch to combis is to remove the risk of Legionnaire's disease due to stored water. The risk of contracting Legionnaire's disease is not high, but the consequences can of course be very serious. Does this mean that combi boilers are a bad thing? Not necessarily. Housing associations with a programme of replacing system boilers with combis may still wish to do so to reduce maintenance costs – but some may be mistakenly assuming that energy savings will also be made by installing them.

The study indicated that 48 per cent of residents in high-SAP (80-plus) homes still considered them draughty. New build homes should have had air-tightness included in their specification, and so the reasons for these draughts should be looked into.

The main reason to keep delivering work programmes that improve SAP is to improve comfort in people's homes. While having warmer homes is of course a good thing, it is only half the job. Addressing behaviours which waste energy at the same time as carrying out energy efficiency works will enable the resident to benefit not just from the 'comfort take' but from lower energy use too.

The energy efficiency of homes in the UK has improved enormously in recent decades. A typical UK home would have had a SAP score of just 17 in 1970, while by 2011 this had risen to 56.7. Housing association homes have a SAP average of 66, while for homes in this study the average was 69. Total energy use per home nationally has fallen by 19 per cent since 1970, a figure which includes significant changes in electricity use because of consumer electronics, refrigerators and home computing. The most significant reductions in energy use have been led by innovations such as double glazing, cavity wall insulation and insulating hot water cylinders.

Continued investment in energy efficiency will lead to further reductions, but SAP should not be the only driver of this. Measures that reduce draughts; energy wastage from heating water; and education about heating controls and energy usage are all ways that may not increase SAP by very much, but will improve comfort and reduce bills.

Quotes from residents

I think your study is a useful asset to try and help people like me, on a pension and the not so well off.

Mr S, Newcastle

Enjoyed taking part in these studies, you learn things new everyday on how to save energy.

Mrs P, Sunderland

I was pleased to contribute to your survey. I hope this helps. Hopefully helps to understand why we use so much gas and electricity. Would be grateful for any feedback on how to use less and how to control my heating properly. I will be pleased to help in any other surveys to help you.

Mrs T, Newcastle

I am bewildered why my monthly payments are so high. I think £60 a month for one person in a new build, that uses below average fuel keeps having the payments increased. I am a widow and receive no benefits whatsoever.

Mrs F, Bridgewater

5,600 meter readings

524 two-bedroom homes

13 housing associations

£1974 highest annual energy costs

£253 lowest annual energy costs

37 weather stations

National Energy Study

SUSTAINABLE HOMES

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