Local Energy Assessment Fund

Whole House Retrofit Assessment Method

VERSION 2: JULY 2012

URBED (Urbanism Environment Design) Ltd 10 Little Lever Street, Manchester, M1 1HR **T** 0151 200 5500 info@urbed.coop www.urbed.coop

Contents

April 2012 (Version 2: July 2012)

This report was prepared by Charlie Baker Eleni Kalkantzi and Marianne Heaslip at URBED.

It was prepared on behalf of the Carbon Coop for the Local Energy Assessment Fund from DECC.

URBED (Urbanism Environment Design) Ltd , 10 Little Lever Street, Manchester, M1 1HR

T 0161 200 5500 info@urbed.coop www.urbed.coop

Carbon Coop

T 0161 408 6492 info@carbon.coop http://carbon.coop/

Executive Summary

Purpose of study

This study was commissioned by the Carbon Coop to help develop an assessment tool and methodology for whole house retrofit. The Carbon Coop is interested in both the promotion of carbon reduction methods generally, and potential involvement in the 'Green Deal' household retrofit programme, due to be launched in Autumn 2012.

This methodology is not just about the energy modelling tool used, though this is important, but also the need to consider real-world constraints and preferences in householders decision making, and how this will influence the choice of measures deployed. These influences may include physical constraints, such as the size and construction of the property, as well as social and financial constraints, such as limits on 'pay as you save' type returns among households that have already undertaken basic measures and have generally low levels of energy use.

This study has enabled an understanding of the implications of existing real life situations for the Carbon Coop's whole house retrofit offer. This is likely to have an impact on financial structures and models, education and engagement programmes, and marketing and development. Through all of these it will affect the future carbon dioxide emissions of Carbon Coop members.

Key Findings

In carrying out the twenty example whole house assessments for this study a number of key discoveries have been made. In many cases these confirm or reinforce findings made by URBED on previous projects, and others in the published literature on whole house retrofit:

- By taking a 'fabric first' approach, it is technically possible to achieve the 2050 80% carbon reduction target set out in the Greater Manchester Domestic Retrofit Strategy on many of the most common house-types in the Greater Manchester area. That is an emissions rate of $17kgCO_2/m^2.a$ and primary energy use of $120KWH/m^2.a$ can be reached. However, whether these measures can at present be paid for in full through a mechanism such as the Green Deal is more doubtful. As the Carbon Coop model already assumes, a level of subsidy will be required in most cases until construction costs can be reduced by around 30%.
- The target SAP rating for houses to meet the above 2050 carbon and energy targets is between 91 and 97. This is potentially significantly higher than had previously been considered in retrofit programmes.
- There is significant interest in whole house retrofit among householders in the Manchester area. The whole house assessments offered by the Carbon Coop were over-subscribed by a ratio of at least 2 to 1.
- We understood that those most likely to apply for a whole house assessment through the carbon coop would be potential "early adopters". Almost all the households surveyed described themselves as highly environmentally concerned and were involved in action groups on environmental issues and campaigning. Carbon dioxide emissions reductions were given as a key reason for wanting to carry out work by most, with saving money on utility bills and improvements in comfort a second order consideration for many.

- Over half the homes surveyed had problems with air quality or condensation. This is likely to be due in many cases to under-heating and poor ventilation. Many households were very energy conscious, so sought to minimise the use of heating systems and heat losses through ventilation. This has immediate implications for the health of occupants, especially the fifth of households that included people with asthma or allergies. It also has implications for 'pay as you save' type financing models if actual rather than modelled energy costs are considered. Heating behaviour in some cases has already led to significant reductions in energy use of up to 56% as compared with the assumptions made in SAP. By undertaking whole house retrofit up to the full target, these houses would not receive the financial benefits projected in the calculation of the 'Golden Rule'. However, if this is understood, many may still be willing to participate to some level to improve the environmental performance and comfort of their properties.

- Many of those who are interested have already undertaken 'basic measures' to improve their household energy performance, such as installing new windows and top-up loft insulation. However, many were unsure of the standards that had been achieved by these measures. For example they were unable to say what energy rating double glazing installed had achieved. This suggests there is need for education of both householders - so they understand the importance of these details - and the suppliers and installers of these measures. Otherwise it is likely that opportunities for improved energy savings by small improvements in the performance of elements such as windows, which are often installed on an 'as and when' basis rather than as part of a wholesale retrofit programme, may be missed. It also shows the need for clear targets for carbon emissions reductions, so that householders and installers understand the overall aims of any retrofit programme.

- Some householders have gone further and installed low carbon and renewable energy technologies, such as solar thermal systems and MVHR units. However, in many cases these have been installed before work to improve the fabric performance of properties has been undertaken, thereby undermining their effectiveness - for example by installing MVHR without carrying out significant improvements in fabric air-tightness. This means that many of these systems are not making as large a contribution as they could dto household energy savings.

- Many of those who have undertaken work are now 'stuck' - unable to go further by themselves due to an uncertainty around what is best to do next and a lack of technical know-how. This demonstrates that even though households may consider themselves to be committed environmentalists, there is still a need for clear and trusted technical guidance, as well a confidence building education programmes for householders. The Carbon Coop is well situated to deliver on some of this.

- The levels of demand reduction needed to meet the targets are considerable and there comes a point when the last step can be easily reached by installation of photovoltaics. There needs to be a debate as to whether how the extrapolation of this approach across UK housing stock would impact UK electricity supply management through the national grid - and an investigation of the potential for other solutions, such as decentralised and community scale energy generation - which may be more effective in some cases.

- Whilst many of these households have little chance of gaining significant financial benefits from a full 80% whole house retrofit because their energy use is already relatively low and because of the still quite high costs of some retrofit measures, they could benefit immediately from low energy ventilation solutions, more flexible and sensitive heating or appliance controls and products that would assist in monitoring their internal environment. These 'interim' measures would have the potential to improve occupant health whilst also making sure that energy in the households was used in the more effective way possible.

Further Research

It seems unlikely that financial incentives alone through a 'Green Deal' type scheme, with the calculation of the Golden Rule using SAP, will be sufficient to immediately stimulate a large market in whole house retrofit in Greater Manchester. Early adopters, who could help to develop the market for more cautious households, have in many cases already reduced their household energy use through basic improvements or behaviour change, and therefore appear less likely to reap immediate financial rewards - though in the longer term, with increased fuel price inflation, they may still benefit financially. However, in many of these houses there are significant problems with air quality and condensation. The following suggestions for further research and action by the Carbon Coop are therefore made:

- The Carbon Coop should investigate whether some of these potential early adopters are willing to take part in whole house retrofit for perhaps limited financial rewards, but because of the other perhaps less tangible benefits around improved comfort, indoor air quality and general environmental performance and resilience.
- Evidence should be gathered on the potential for retrofit works to improve the value of properties, in the same way as a new kitchen or bathroom does currently - providing a secondary reason for householders to participate in retrofit.
- The Carbon Coop should continue to develop peer learning networks, so that householders can learn from each other how to ensure energy efficiency whilst also living in a healthy indoor environment. This should include work on monitoring of energy use, temperature and humidity in homes, with a view to improving health and well-being as well and energy performance.
- Supply chains need to be developed to ensure that contractors are educated in the requirements of a whole house retrofit and can reduce the costs by gaining experience in the sourcing of materials and methods of installation. Work should be carried out with suppliers to develop products to assist in better controls for electricity use and heating and subsequent monitoring.

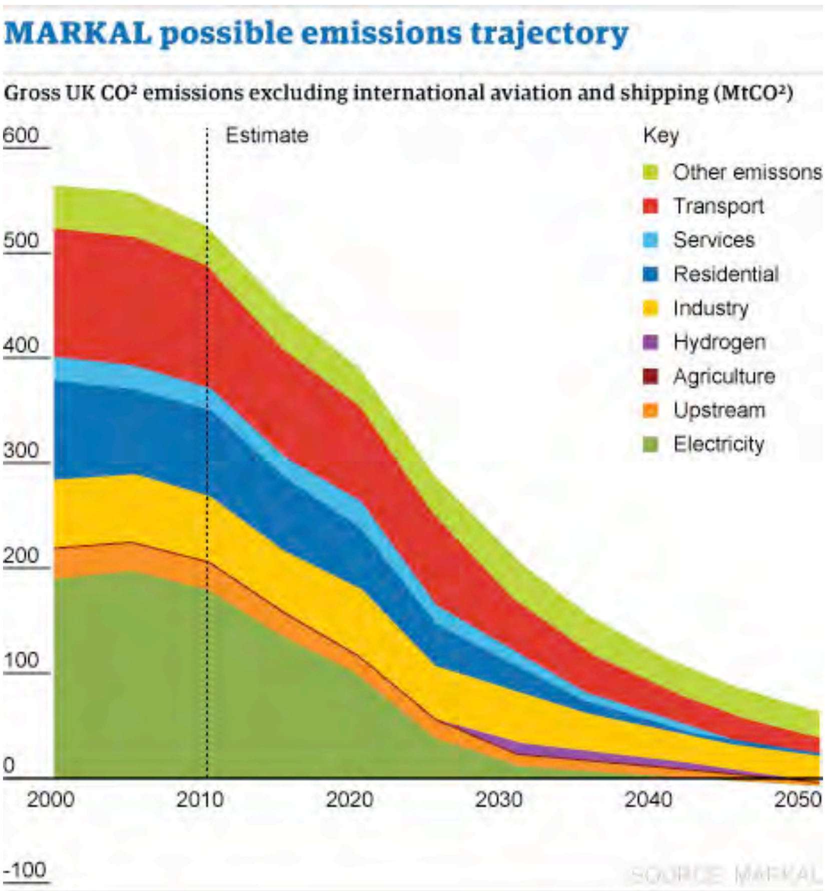
Introduction

The Carbon Co-op

The Carbon Coop is a Manchester based community benefit cooperative, which brings its members together to explore how they can best improve their environmental impact and promote the development of carbon reduction measures. This is built on the idea of a 'Community Green Deal' developed by URBED for the Sustainable Housing Action Partnership in the Midlands (www.shap.uk.com). This sought to develop an approach to whole house retrofit that is community led and community serving. As a mutual model it benefits from being controlled by those it provides services and advice to - thereby helping to overcome the trust issues so often cited as a reason for people to mistrust the advice given on home improvements as well as closing the loop between households and suppliers of both construction work and finance

This structure also helps to facilitate a peer-learning process among its members. For example in whole house retrofit those 'pioneers' are able to share knowledge about which measures work best, and what the process actually involves with those who follow-on from them. In addition, if members are able to work together to increase their purchasing power they can bring down the costs on products such as wall insulation, solar panels, or highly efficient appliances.

The carbon coop also has a sister organisation in the 'Carbon Re-Investment Society' (CRIS), which will provide financing services for low carbon investment in energy efficiency and renewable energy. As a mutual with no shareholders to satisfy, this should provide a trusted and low cost financing mechanism.



Graph showing the projected reductions in UK CO2 emissions by sector by MARKAL.

Why whole house retrofit?

The need for whole house retrofit of the UK housing stock is now widely recognised. The UK legislative target is an 80% carbon dioxide emissions reduction on a 1990 baseline by 2050[1]. The current rate of housebuilding that means at least 80%, and probably more, of the homes that will exist then are already built[2]. Housing as a sector currently contributes at least a quarter of the UK's carbon dioxide emissions[3]. A significant improvement in the environmental performance of housing therefore needs to be made if the UK is to meet its current legislative obligations and mitigate the risk of climate change. This need for action is repeated and emphasised at a local level in the Greater Manchester Domestic Retrofit Strategy[4], produced in 2011.

However, the benefits of whole house retrofit go beyond the purely environmental. With rising energy prices, fuel poverty is an increasing issue for many UK households, exacerbated by our existing poorly performing housing stock. This in turn means that many people are under-heating their homes, leading to problems such as excess cold and damp, which in turn can have adverse effects on the health of residents and the maintenance needs of their houses

The need to improve the housing stock has been acknowledged by both government and industry, though progress is still relatively piecemeal. Programmes such as the Technology Strategy Board's 'Retrofit for the Future'[5] have provided learning for the industry, whilst the interest of local authorities, contractors and supply chain partners in the West Midlands led to the development on the 'Community Green Deal'[6] model with the support of the Homes and Communities Agency, and the Greater Manchester Domestic Retrofit Strategy[7]. These projects and strategies suggest that there are significant potential benefits to local and regional economies through local supply chain development and manufacturing to satisfy the retrofit market. Whole house retrofit has the potential to contribute wide-reaching environmental, social and economic benefits to the UK and its regions.

This potential has been recognised by central government, with the launch of the Green Deal programme due in autumn 2012[8]. This pay-as-you-save model should allow householders to make improvements to their homes through retrofit without having to pay up-front costs and instead repaying a loan fixed against their property through a charge on their electricity meter. These repayments must meet the 'Golden Rule'; that is they must be less than the savings made by the retrofit, so that householders are guaranteed to still pay less overall for their utility bills. However, the savings and repayments will be calculated using a variation of the 'Standard Assessment Procedure' (SAP), currently used to assess compliance with building regulations and produce energy performance certificates (EPCs)[9].

---

1 Climate Change Act 2008 available at http://www.decc.gov.uk/en/content/cms/legislation/cc_act_08/cc_act_08.aspx

2 www.statistics.gov.uk/hub/people-places/housing-and-households/housing-stock

3 DECC Statistical Release 31st March 2011 Sustainable Development Indicators

4 manchesterismyplanet.com/_file/cyncF7KGUn_107331.pdf

5 www.retrofitforthefuture.org

6 www.shap.uk.com/projects/shap10

7 manchesterismyplanet.com/_file/cyncF7KGUn_107331.pdf

8 http://www.decc.gov.uk/en/content/cms/tackling/green_deal/green_deal.aspx

There has been much debate about this in the industry, since as a standardised modelling procedure this cannot fully take account of variations in energy use behaviour between households - and therefore savings may not in reality be as great as projected under this calculation, breaking the golden rule. Recent press coverage suggests that there is a significant reputational risk to 'Green Deal' providers if this is not fully understood or accounted for.

One of the key purposes of this study has been to look at the Pay as You Save approach as a means of delivering houses retrofitted to the 2050 target from the perspective of the Carbon Coop, using 20 real-life case studies of people interested in undertaking retrofit measures in their homes.

Approach

The Carbon Coop's primary purpose is to enable its members to pool their resources and to deliver economies of scale in the cost of materials and services that its members want to buy to reduce carbon emissions and therefore combat climate change in the most effective way possible. The approach to whole house retrofit taken for this study is therefore to prioritise the carbon reductions needed to meet the 2050 80% reduction on a 1990 baseline target, as set out in national legislation and local policy. An absolute rather than a relative target is used, with each household expected to achieve the same result, no matter what their starting point. In this respect it mirrors the 'contraction and convergence' approach to carbon emissions at a global scale. This clearly defines where we need to get to, rather than using the current inadequate situation as a basis for incremental improvements - leading to an approach based on the response required by climate science, rather than current assumptions about what is possible. In this way it avoids the creation of 'false anchors' and ensures that all that can be done is done to achieve the reductions needed.

The chosen target for this study is based on that used in the Technology Strategy Board 'Retrofit for the Future' programme, and adopted in the Greater Manchester Domestic Retrofit Strategy: 17kgCO_2/m^2.a and 120KwH/m2.a. This is derived from an 80% reduction in emissions from a notional 1990 household. It should be noted that this target is for all of the household emissions and energy use and so includes all appliances, rather than the SAP rating which only includes energy use and emissions from fixed items such as lighting, heating and ventilation.

However, carbon emissions reductions are not the only concern of the carbon coop and its members. Fuel poverty and the overall costs of retrofit are also to be considered. As is household comfort and general health and wellbeing, and wider issues of environmental degradation. A cost-effective fabric-first approach is taken. Demand reduction for heating and power use is prioritised over the addition of new renewable and low carbon energy sources - leading to a greater degree of resilience of the overall household systems. By taking a 'whole house' approach to these measures, for example by assuming windows will be replaced at the same time as any wall insulation is carried out, savings can be maximised by careful detailing to minimise thermal bridging and air-leakage. Only once demand has been reduced are such measures deployed. Material selection has also sought to minimised embodied energy and carbon, the use of non-renewable resources and substances toxic in manufacture, use or disposal.

Assessment Method

The Green Deal assessment method currently being developed for launch in autumn 2012 is based on SAP and delivered in two parts; an asset based assessment, using standardised assumptions about occupancy, and an occupancy based assessment[10]. The assessments outlined in this report are in three parts. The first is the evaluation of the built asset using SAP 2009, covering only 'regulated emissions' - those associated with fixed elements of the building such as heating, lighting and ventilation. The second part again uses SAP/BREDEM based calculations to derive a standardised figure for the whole building, including 'unregulated' emissions for cooking and appliance use. This means that each home as an 'asset' can be assessed against the retrofit emissions and energy use target set out above. The third part uses the occupant

10 www.gdtool.bre.co.uk

questionnaire and actual utilities data where available as a check against this figure, and allows a narrative set of recommendations to be developed tailored to each individual household. In many cases this may not affect the major retrofit works required - but instead will focus on appliance energy use and behavioural measures.

SAP was chosen as the modelling tool because it will form the basis of the official Green Deal Assessment tool. Full SAP was used rather than the reduced version, rdSAP, because we wanted to better understand and be able to manipulate the full the range of variables which are likely to affect household energy use. rdSAP makes a set of assumptions about energy use based on the age of the property rather than its actual construction, and we have found in the past that this can lead to wildly varying estimates of a building's actual performance.

Methodology

Household Selection

We had funding to study twenty properties. In order to maximise research value, the desire was to end up with properties as representative as possible of the makeup of Greater Manchester's housing stock. Participants were selected from applications received through the Carbon Coop website and contact list. We specifically wanted to work with likely early adopters, as their experiences of retrofit will influence its future success. Models of 'Green Deal' deployment, including URBED's own 'Community Green Deal', assume that early adopters will set the tone for this ambitious programme as it is rolled out. We wanted to understand their particular needs and any issues that would affect the Carbon Coop model. There were more applicants than we were able to provide assessments for, so a further selection process was carried out by the Carbon Coop team, to ensure a representative spread of common Greater Manchester house-types.

Site Visit

The same team of three undertook each house visit at a time convenient for the occupier; one taking measurements, another photographing and a third conducting the resident questionnaire. This meant that disruption for the residents could be kept to a minimum, whilst as much information as possible was gathered. The purpose of the site visit was to ensure that any measures selected both fitted the house but also to respond to any serendipities that might arise in particular houses such as a very deep void under suspended floors or particularly fine internal or external detailing that would need to be preserved.

Asset Modelling Tool

The Green Deal assessment method is to be based on the Standard Assessment Procedure (SAP). This is now a very complicated process with a guidance document of 160 pages. As a result many of the tools available to use SAP operate as a "black box", necessitating all of the input data to be fed in before a result is obtained. This makes it difficult to use as a tool for assessing a design approach as it is developed. Given the primacy of this assessment tool in UK practice and legilislation, URBED developed an open spreadsheet version to enable it to be used as much more of a design tool. This allows indepth comparison of different measures while also allowing the effect on the results to be assessed on a measure by measure by measure basis.

Occupant Questionnaire

A pilot version of an occupant questionnaire was delivered to each household during the site visit. This contained general questions on the household and their current levels of satisfaction, as well as specific questions on current bills and energy use related behaviours. This allowed the 'as existing' SAP results to be compared with actual energy use. This was important to understand as published studies have uncovered significant differences between modelled and actual energy use in both domestic and commercial buildings[11].This also allows potential for suggested measures to be tailored to the needs and priorities of each occupant to some degree. For this study this process produced descriptive and narrative results, though it is hoped that as a larger database is built through future assessments, and the questionnaire itself is refined, more definitive outputs can be produced.

11 Janda (2011) 'Buildings don't use energy, people do', Architectural Science Review 54:1

Community Engagement Events

As part of both this and a sister study for LEAF on community heating systems, a series of engagement events were held in neighbourhoods around Manchester. The aim of these was to gauge current understanding of and enthusiasm for potential carbon reduction measures such as whole house retrofit and community heating networks.

Retrofit Measures

Using the SAP spreadsheet tool developed by URBED, proposed specifications to meet the absolute 80% carbon reduction target of $17kgCO_2/m^2$.a and $120KwH/m^2$.a primary energy use were developed. This was done in key stages on the basis of ease of delivery appliances and household controls such as master switches and heating zone controls basic fabric measures such as draft proofing, increased loft insulation and sealing the ground floor intermediate measures such as passive stack ventilation, boiler replacement where appropriate, and replacement of doors and window glazing units, underfloor insulation where accessible from an undercroft or cellar major works such as external wall insulation, window replacements set into this, underfloor insulation with access from taking up floorboards, perimeter floor insulation, internal wall insulation, air tightness works additional renewable measures such as photo voltaics sized to meet the outstanding reduction URBED were able to use their experience of built retrofit projects to take into account any buildability issues. An advantage of maximising fabric improvements first is that the speed of technological change is very slow in the case of some materials, for example wall insulants, and much slower than mechanical and electrical kit. Over the next 40 years as we move towards the 2050 target, it is likely that mechanical and electrical systems may be replaced several times over, whilst if of high enough quality, wall insulation and windows may last the lifetime of the building. A super insulated house is therefore much more future proofed that a house equipped with “eco bling”.

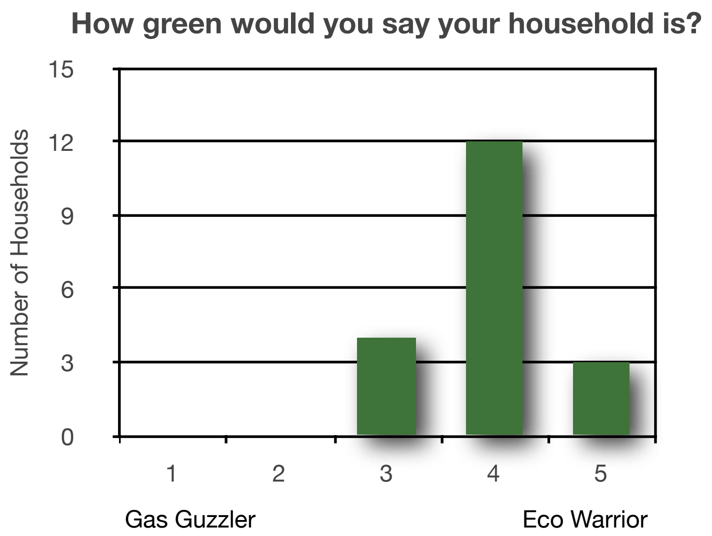
Householder Reports

A short four page report was prepared for each householder, which provided information on how their property was performing at present according to SAP, a comparison with their actual utility bills, and a description of the suggested measures to achieve the 2050 target. Informal advice was also given on immediate small-scale improvements to household comfort and indoor air quality.

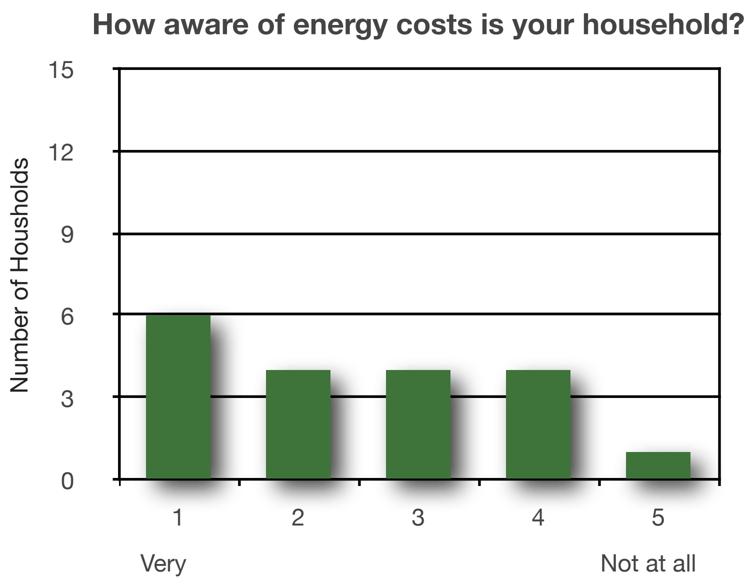
Existing Household Context

Residents

A range of household make-ups were involved in this 20 household study - from single people, to older couples and families. The vast majority were owner occupiers, though there was also three social tenants out of the twenty. Many saw themselves as committed environmentalists, with the majority identifying themselves to be the 'eco-warrior' end of the scale when asked to rank themselves from 1 to 5. All had some awareness of environmental issues, and many already felt that they'd taken environmental improvements to their homes as far as they could on a DIY basis. These households are therefore some of the likely early adopters of whole house retrofit.

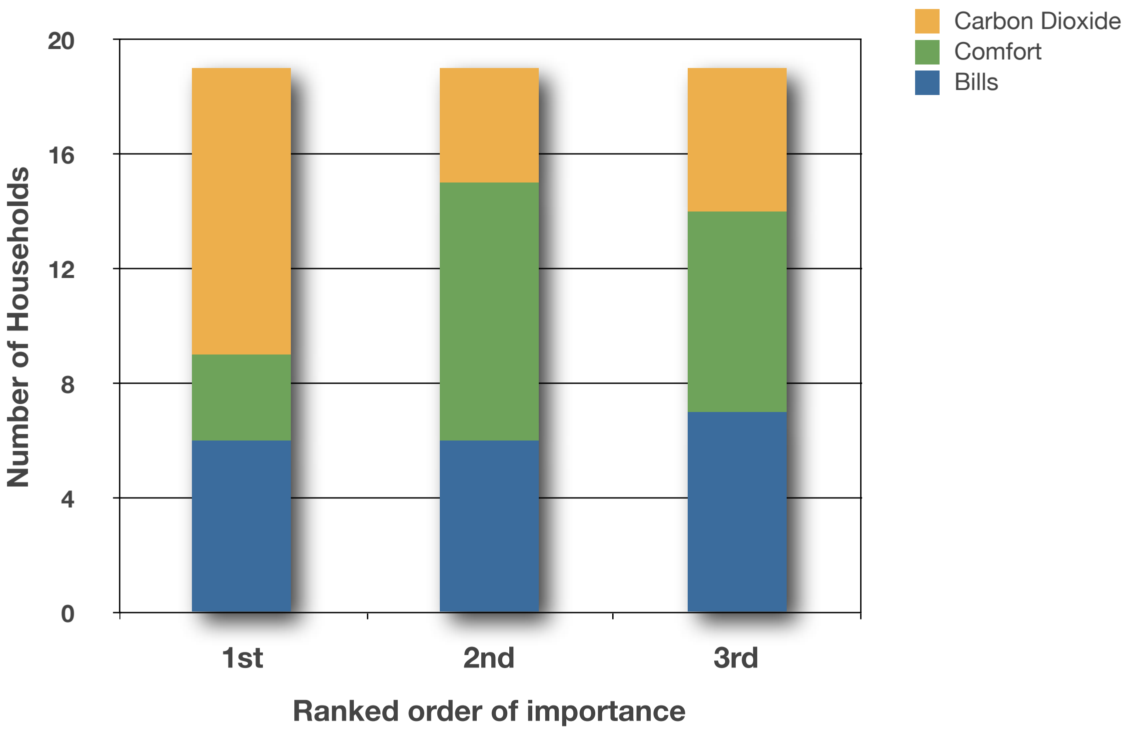


Despite this, many had a limited awareness of how much they currently spent on energy, and how their homes performed generally, though there was a roughly even split across all households when asked about energy cost-awareness.



When residents were asked what their motivations were for taking part in the study, at least half mentioned the desire to make environmental improvements as a key factor, and many of these were already involved in local environmental groups and campaigns. This tallies with the fact that the majority of households cited a desire to make carbon emissions reductions as their first priority in undertaking any work. There seemed to be a feeling among this group that they have already done many of the simple measures to improve their energy efficiency, and they were now uncertain about what to do next.

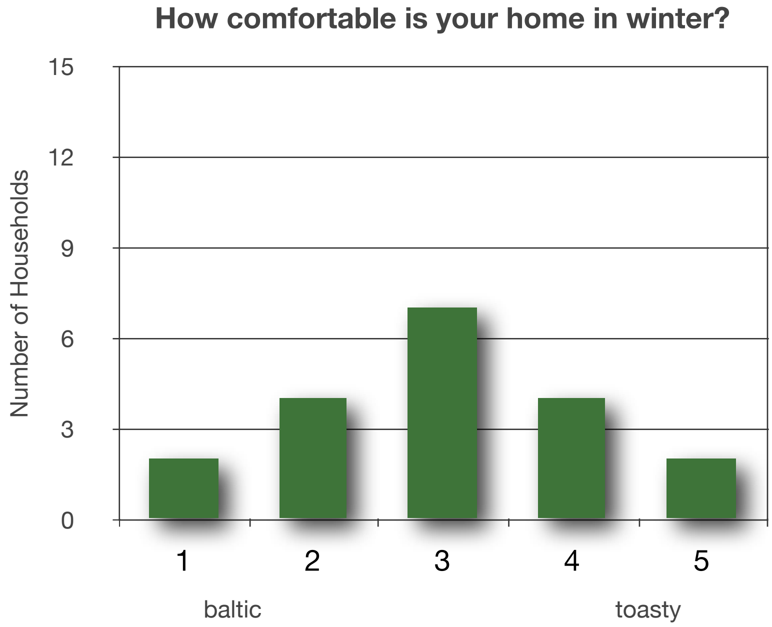
The second most mentioned factor by many was the desire to make their homes more efficient and cheaper to run. Despite this, almost all households struggled to supply us with accurate data on their current energy use and costs. There seemed to be a general awareness that fuel costs were increasing, but even among the committed environmentalists, a lack of awareness of exactly how much energy they were using. There may be a role here for the Carbon Coop to step in and help households better understand and monitor their energy use, and make decisions about what to do beyond DIY measures in energy efficiency.



Over 50% of the households surveyed are either at home all day, or work from home one or two days a week using computers. This means that the assumptions around domestic heating patterns and occupation rates made in SAP and other energy models will not hold true for these households.

Physical context

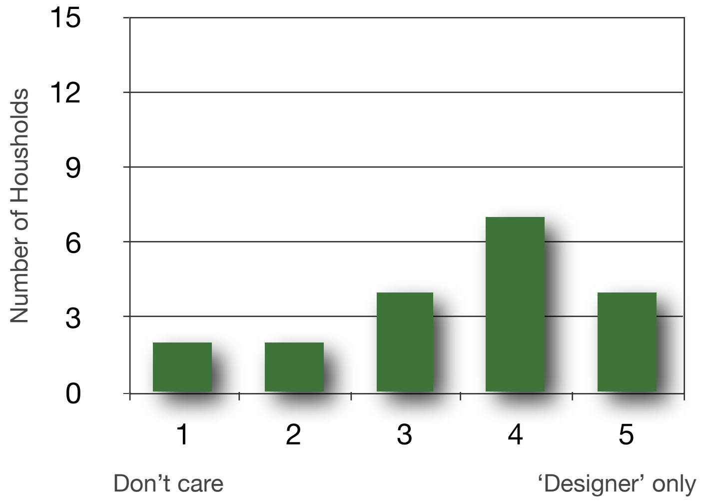
The houses and apartments assessed varied in size, age and construction - though given the geographic location of the study, older terraced houses tended to dominate. Almost all have some outdoor private space. One of the most notable features during the visits was the number of properties that had obvious problems with damp, condensation and mould. With the Decent Homes programme in social housing now almost complete, many of the worst of these issues are now in private housing. Approximately 50% of residents reported feeling cold in winter, and that their homes were expensive to heat and that air-quality is often poor. Residents seemed to cope with this by putting on extra layers of clothing rather than turning up the heating, and in some cases had covered or taped over vents to save energy. If they were also drying clothes inside on clothes horses during the winter months this also increased internal humidity. Whilst this may be admirable behaviour for saving energy and money, it has implications for the health of these residents, especially the fifth who reported issues with asthma or dust allergies. It also means that the building fabric in some cases is being damaged by excessive condensation, damp and mould.



Above: *Mould growth caused by surface condensation and covered vents in the properties.*

However, not all householders reported discomfort, and many houses showed no signs of damp or other structural problems. Many of the homes were in very good condition and due to the age of the properties had features which the residents (and the design team) wished to preserve in any retrofit, such as original fireplaces and coving. This is perhaps especially significant for some of the likely early adopters surveyed, for whom the aesthetics of any work carried out would be significant.

How important are aethetics to you in whole house retrofit?



Many of the householders have already invested considerable sums of money on improvements to their properties. Almost all already had double glazing at least in part, many had new boilers. However most were unable to say what level of performance their windows had achieved, making modelling the existing condition difficult and suggesting that opportunities for maximising performance in these areas may have been missed without the householders realising it.

Perhaps surprisingly, many households had only limited controls on their current heating systems, with at least 25% having no thermostatic controls at all. Almost all wanted a system with a greater degree of control over their heating systems, and many were already using TRVs.

A number of households had gone further and installed renewable energy and other technologies, such as solar thermal or PV systems. In many cases this had been done before other possible energy efficiency improvements had been made to their homes, limiting the effectiveness of these systems in some cases - for example having MVHR units installed before carrying out air-tightness works. Again, this perhaps shows that there is a role for the Carbon Coop in educating householders and perhaps also the likely installers of these technologies.

Right: Existing gas boiler with cryptic heating controls.

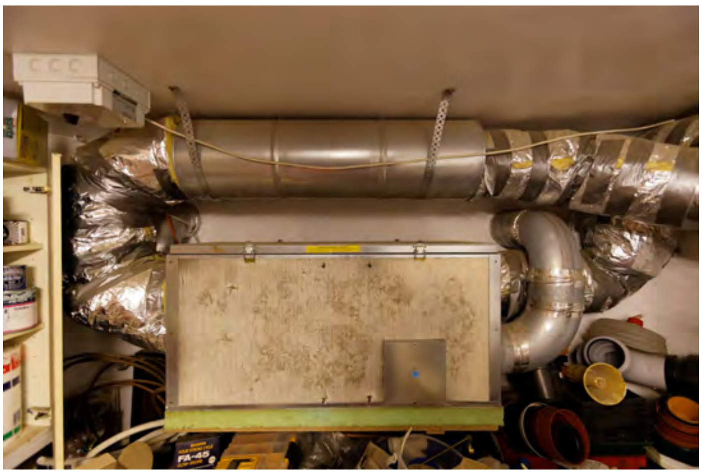
Above: One of the houses surveyed with original fireplace and coving and curved walls to bay window.

Right: Several of the houses presented problems in areas that would normally be recommended for external wall insulation, due to the lack of room around windows and the positioning of services.

Above: Solar thermal system with external water store, regarded as unsuitable for the UK climate. Evidence that though well meaning, residents aren't always well advised or able to make the right choices.

Left: An existing small solar thermal evacuated tube system on an off-gas-grid property.

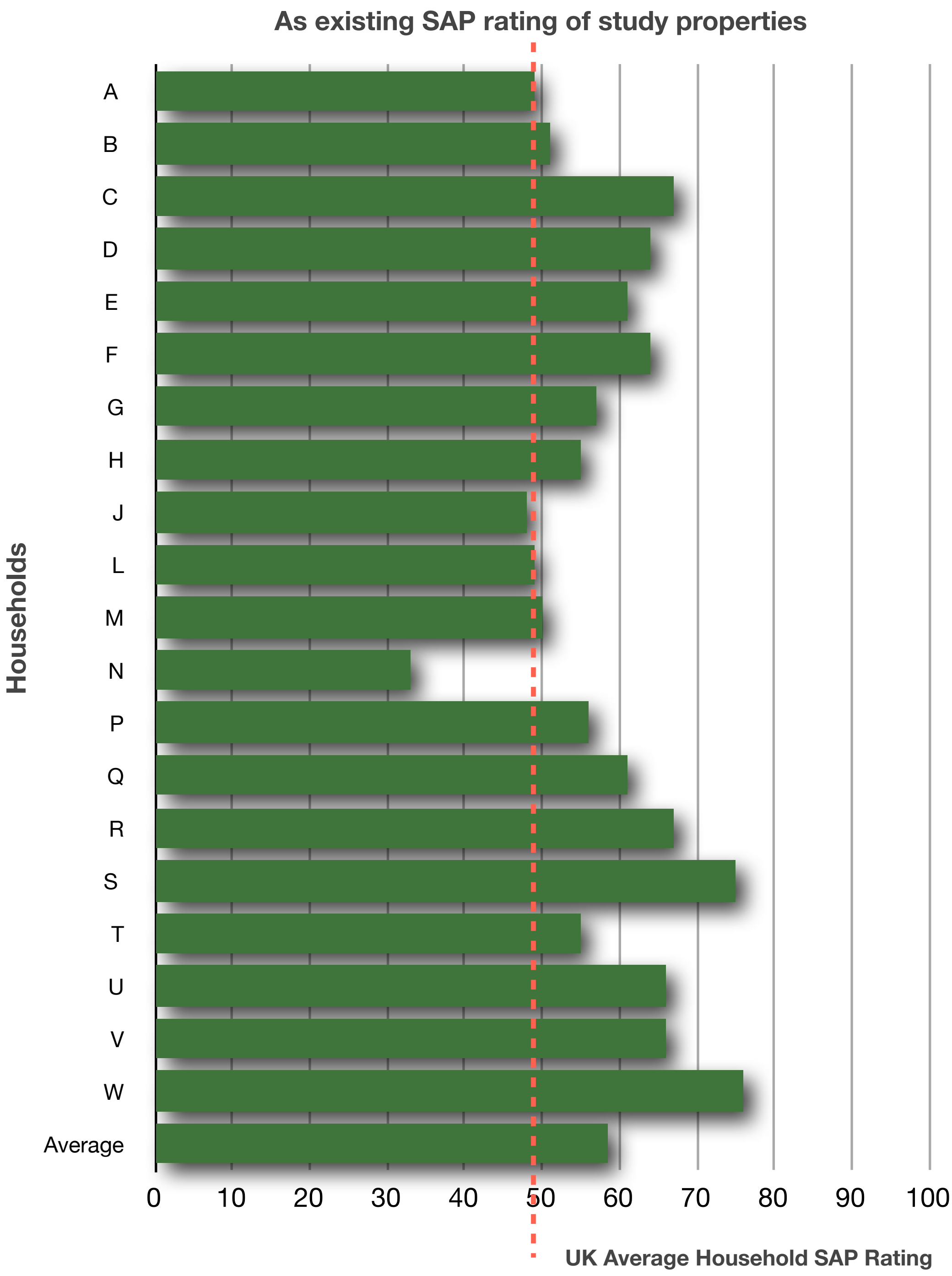
Bottom: An MVHR system in one of the houses of uncertain efficiency.



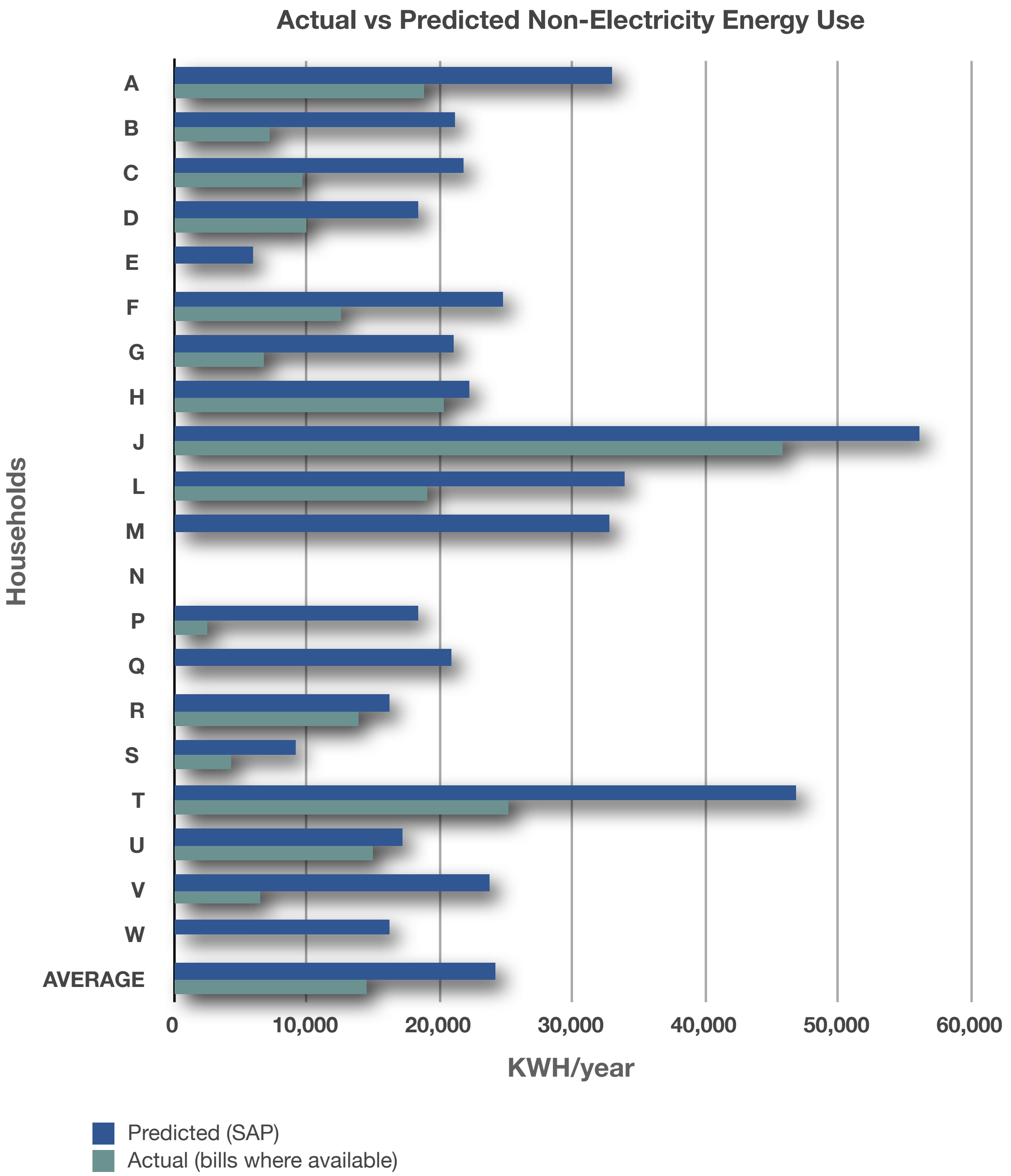
Household Energy Performance

Energy performance

Following the site visits, the data on each of the properties was entered into the SAP tool to produce figures for current energy use, carbon dioxide emissions and a SAP rating. This was then compared with the actual billing data for each household (where this was available).

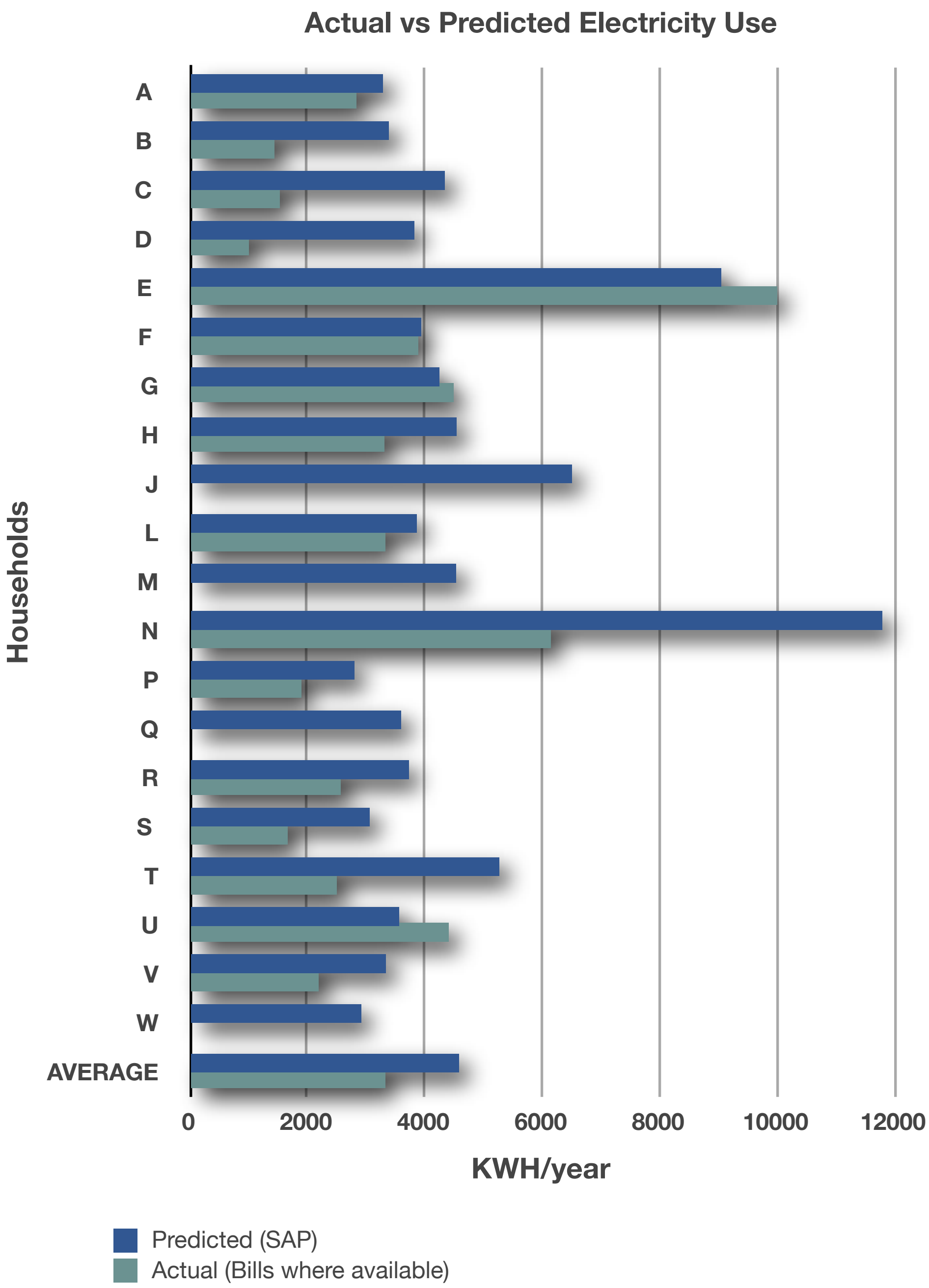


The existing SAP ratings for the properties in this study are scattered around the UK's average household SAP rating of 49.8, with the majority being slightly higher than this. It should be noted that some of those households which are already most involved in the Carbon Coop and environmental issues have the lowest SAP ratings. The overall study average is 59.



There is a large mis-match between the space and water heating needs of the properties as predicted by SAP and the actual energy use of the properties reported in utility bills, with actual energy use in every case being much lower. Whilst this data should be treated with some caution as it is based simply on residents reported bills and is not taken from quality controlled monitoring, it does seem to tally with the conclusion above that many residents are under-heating their homes. It should also be noted that many residents, even the most 'environmentally aware', were unsure of their own energy use - suggesting there is room for understanding to be improved here even amongst the most committed households. Heating regimes are very different to those assumed in SAP. Householders appear to accept much lower average internal temperatures, and wear extra clothes to deal with this. Many also reported only having the heating on for relatively short periods of time, and the rigorous use of Thermostatic Radiator Valves (TRVs) to ensure that they only heat the rooms they are using, rather than heating the whole house.

This finding has significant implications for any 'Pay As You Save' retrofit financing model, as it suggests that a lower rate of actual savings possible among these early adopters, because they have already saved significantly on assumed and average energy use through behaviour change. As some of the people most likely to be 'early adopters' in any Green Deal due to their level of environmental commitment, they also appear some of the least likely to be able to benefit financially.



Comparing electricity use from SAP with real world evidence suggests that energy use has been over-estimated for this group on the whole, though it does appear to be closer in most cases. Again, whilst this data should be treated with caution, it does highlight an important issue that should be investigated further. The exceptions to this are where it was noted in the household questionnaires that appliance use was higher than average, either due to higher household occupancy or unusual equipment such as high powered sound systems.

Overall, the average is still below that predicted by SAP, and in some cases is well below this. At least some of this difference is likely to be due to energy-conscious patterns of behaviour among the residents. This may mean there are fewer opportunities to improve energy efficiency through improved or automated controls, as the residents are already controlling their electricity consumption very efficiently.

Retrofit Measures

Measure selection

In selecting the measure for each property a 'fabric first' approach has been taken, as this has proved to be the most cost effective means of achieving large reductions and produces the greatest additional benefits in mitigating fuel poverty and improving thermal comfort. It has also been assumed that many of these fabric works will be implemented at the same time, so that disruption to householders is minimised, and the measures have been chosen where possible to minimise disruption overall - for example by insulating solid floors at the external perimeter, rather than having to dig up and replace floors internally. This also allows the energy saving benefits from measures to be maximised, by taking action to reduce thermal bridging and improve air-tightness at the junctions between elements.

A large number of the houses in this study are older solid-walled properties with timber floors, so there was need to consider issues such as risk of interstitial condensation and the need for vapour-permeability. We also feel that in doing work to improve energy efficiency in use, the embodied energy, carbon and resource use implications of any construction work should also be considered. We have therefore chosen a suite of products that have lower embodied impact where possible, as well as considering toxicity both in manufacture, use and disposal.

Complexity in the specification of mechanical and electrical services has been kept to a minimum. In many cases, where a simple mains gas boiler has been able to meet the target, this is what has been specified. This is to keep installation costs to a minimum, as well as ongoing maintenance costs. In future years, as technologies change and improve, it is the services that are likely to be the easiest and simplest areas to upgrade - much as they are now with boiler replacement. In addition, equipment relating to services has a much shorter useful life than fabric measures - the assumption is therefore that fabric works will only be done once before 2050 while it is likely to be necessary to replace heating systems once, if not twice, in that period.

Gas boilers have also been used in preference to heat pumps where possible for a number of related issues. The main one being that with the current relative costs of gas and electricity, heat-pumps can be more expensive or similarly costly to run than boilers for the same loading - so householders don't benefit financially, and not as much is done to tackle fuel poverty. The second reason is that with the current electricity grid's carbon intensity, heat-pumps offer few savings in carbon terms. If the grid is de-carbonised, this position will change - as it does when a property is off the gas gris or the only alternative is electric or oil heating. (It may be worth in future the Carbon Coop developing their own policy on grid-decarbonisation so that there is greater clarity and consistency on this issue). The third reason related to this is that the amount of money per kg of CO_2 saved means that it is much better to spend the money that would have gone on things such as heat pumps on further fabric improvements. Due to the lifespan of the boilers, heat pumps can be installed later once grid decarbonisation has made them more effective.

Ventilation in most cases has been specified as either natural ventilation or passive stack ventilation. This is because of the difficulty and expense of retrofitting heat recovery or more complex systems in older properties, and the long-term maintenance implications. At the air-tightnesses likely to be achieved in retrofitted properties, the energy savings from heat recovery ventilation are likely to be minimal. This was confirmed when properties were modelled and showed that there was no benefit in savings of either CO_2 or money in installing an MHVR system over a passive stack ventilation system. Where an MHVR system had already been installed it was assumed that this would remain in place.

There are also a number of factors that are not directly to do with energy or construction performance that have influenced the choice of measures. For example, it is almost always best in terms of performance and building physics to specify external wall insulation. However, some of the properties in this study have brick facades with detailing that it was felt desirable to retain, as these form an important part of the character of these homes and the neighbourhoods they sit within. Internal wall insulation was therefore chosen. Similarly, in some case there simply wasn't enough room to install external wall insulation, because the properties were directly at the back of the pavement at the front, or because the position of windows or boundary walls at the rear severely limited the amount of space available.

The following page contains a table outlining each of the fabric measures selected as part of the retrofits. In addition to this general air-tightness and draught-proofing works would be carried out, and detailing would ensure minimisation of thermal bridges.



Some fabric retrofit measures: A new loft-hatch to improve air-tightness and give easier access to loft space, new top-up loft insulation with platform for storage, new woodfibre external wall insulation on a solid brick wall.

Item	Fabric Measure	Comment
Doors	New front and rear insulated timber faced doors external doors to achieve overall U-value of 1.1	
Windows - replacement glazing only	Replace existing glazing units with triple glazed low-E argon filled units with warm edge spacers and 12-14mm cavities.	Where windows have been recently replaced it may be possible to simply replace the glazing to improve performance.
Windows - retained in external wall insulation	Remove existing windows and mount onto the end of 300mm deep timber box screwed and plugged to masonry reveal.	If windows are of a good quality, it may still be possible to relocate them within the external wall insulation to minimise losses from thermal bridging.
Windows - full replacement	New FSC timber frame windows to achieve overall u-value of 0.8.	These may also be positioned on timber box in the external wall insulation.
Ground Floor - solid floor internal insulation	25mm phenolic foam or vacuum insulated panels set between treated softwood battens or floorboards laid directly onto aerogel.	The choice here will depend on the adjustments possible to the level of the floor.
Ground Floor - suspended timber floor	Friction fit hemp or woodfibre insulation batts to a depth of 200mm between joists.	Further air-seal measures may be possible here is necessary.
Ground floor - inaccessible suspended timber floor	Lift two in every ten floorboards and pour in 200mm deep recycled glass pumice, distributed evenly across area under floor and make good.	Works required to air-bricks to ensure adequate ventilation.
Ground floor - solid external insulation	Dig trench around outside perimeter of property and fill with extruded polystyrene carried to the top of the footings.	Care needs to be taken around existing below ground drainage.
Walls - external (breathable)	200mm external woodfibre insulation with 8mm modified glass polymer reinforced render	Use this system where construction needs to be 'vapour open'.
Walls - external (non-breathable)	125mm phenolic foam insulation on cementitious levelling coat with 8mm modified glass polymer reinforced render.	Use this system where a thinner build up is required and there are no concerns about vapour permeability
Walls - internal (breathable)	125mm internal woodfibre insulant with fine finish internal render coat	use this where there are concerns about vapour permeability
Walls - internal (space saving)	vacuum insulated panels with rubber crumb external facing 20mm thick set between reclaimed insulation board battens and cover with board.	use this where space is at a premium and to retain historic covings
Loft - non storage	Top up loft insulation with 300mm formaldehyde free recycled glasswool.	
Loft - for storage	Extruded polystyrene boards laid on top of existing ceiling rafters to a depth of	
Loft - for storage	Strengthen ceiling joists by adding 400x300x18mm pattresses to the side of the joists and fix softwood member to the top of pattresses effectively forming trusses. Covering with 15mm FSC plywood and install 300mm formaldehyde free recycled glass wool	This system allows residents to still use the loft space as storage whilst using a softer and lower-impact insulation material.
Lofts - Habitable	Apply 150mm woodfibre or hemp-fibre to back of wall at eaves and blow polystyrene beads into void between sloping ceiling and roof covering.	

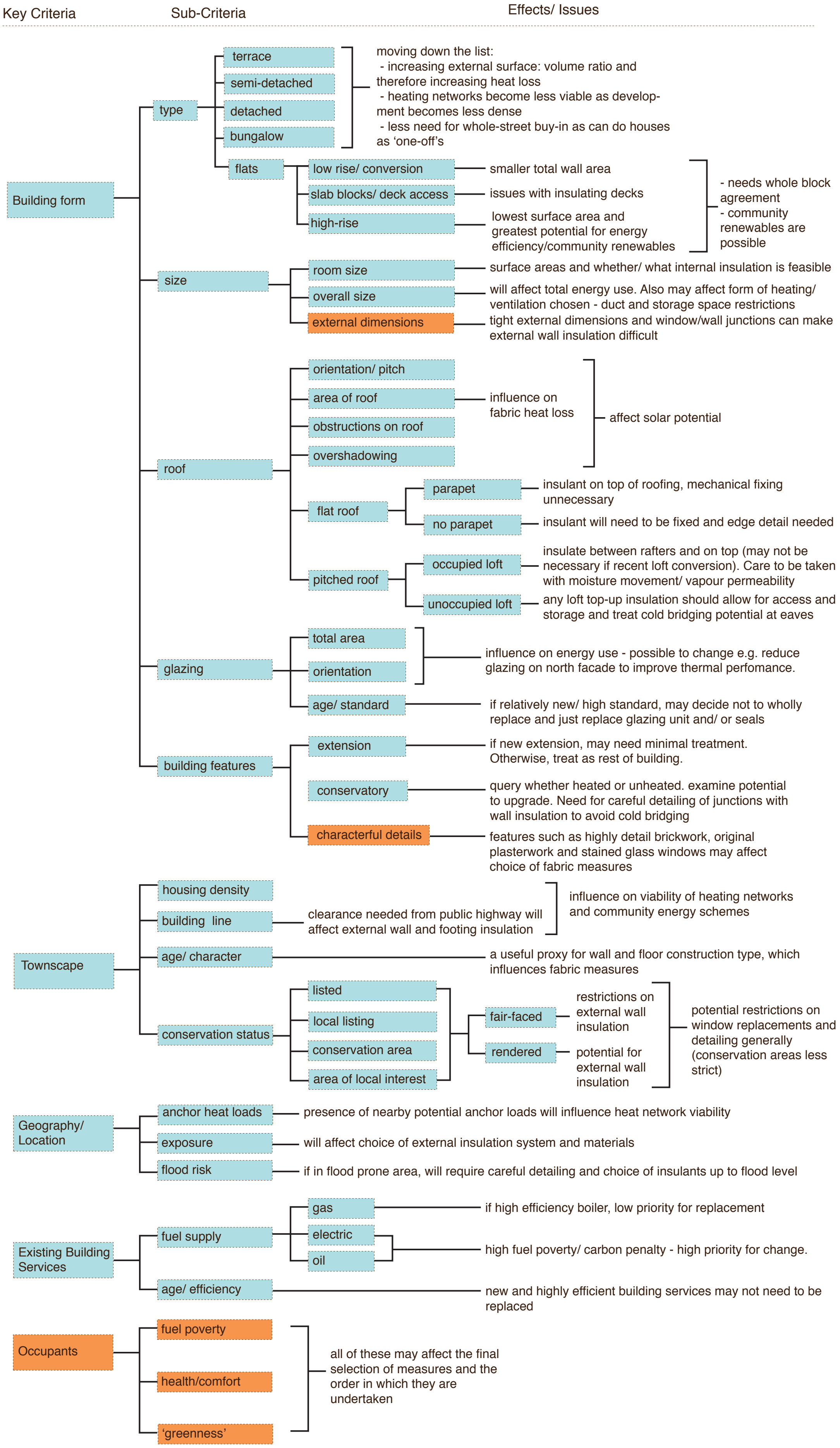
Some example services measures: a clean air act compliant log burner and solar PV panels on the Retrofit for the Future homes in Rotherham.

Item	Services and Appliance Measure	Comment
Heating System - Gas	Install a modern A rated modulating small output boiler	Demand reduction means that the boiler needs to be much smaller
Heating System - Biomass	Install a DEFRA exempt logburner with back boiler and 560 litre thermal store	Use this system where possible when off gas grid
Heating System - Electricity	Install exhaust air source heat pump	Use this when replacing electric storage heating if no other options are available
Water	Fit lo-flow showers and taps and ensure shower is fed from mains system (not electric).	Reducing the amount of water used should also reduce the amount of heating energy needed. Electric showers are very carbon intensive.
Ventilation - Passive	Design and install a ventilation system based on passive stack, either through humidity controlled vents in windows and roof ridge vents or existing chimneys	Assumed as being the default ventilation method
Ventilation - MVHR	Leave in place if already installed	
Lighting	Replace all GLS or bayonet bulbs with compact fluorescents, replace all recessed tungsten downlighters with LED fittings	
Appliances - master-switch	Consider installation of master switches to easily turn off all suitable appliances	To avoid rewiring, suggest a plug based system or remote controlled sockets
Appliances - display energy meter	Supply a display energy monitor	This will improve householders awareness of their energy use

Decision Matrix

The diagram on the following page has been developed by URBED as a tool to understand the complex decision making process undertaken in any retrofit process. This encompasses factors far wider than simply the existing energy performance of the buildings. The items highlighted in orange have been added to the matrix following this study.

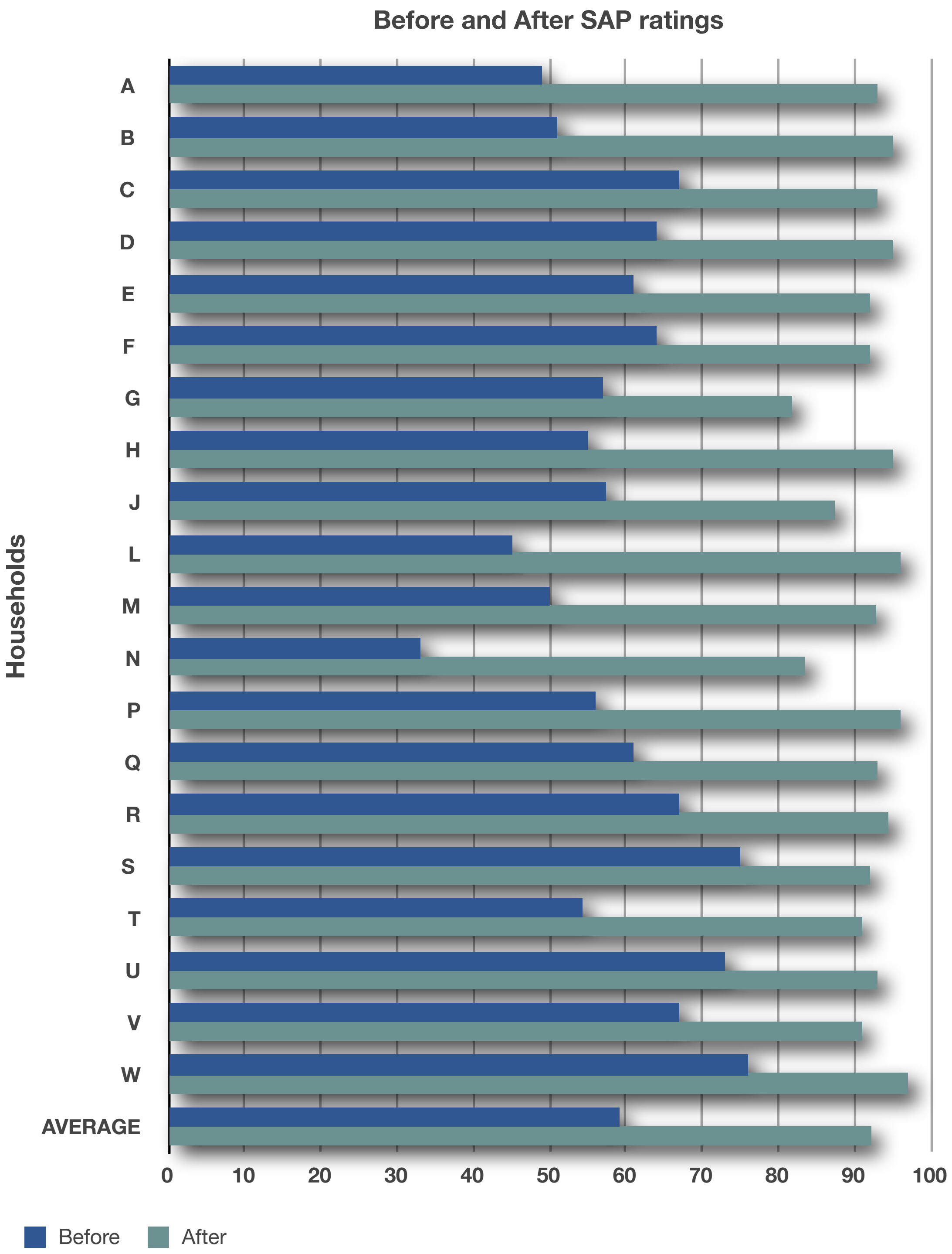
Decision Matrix

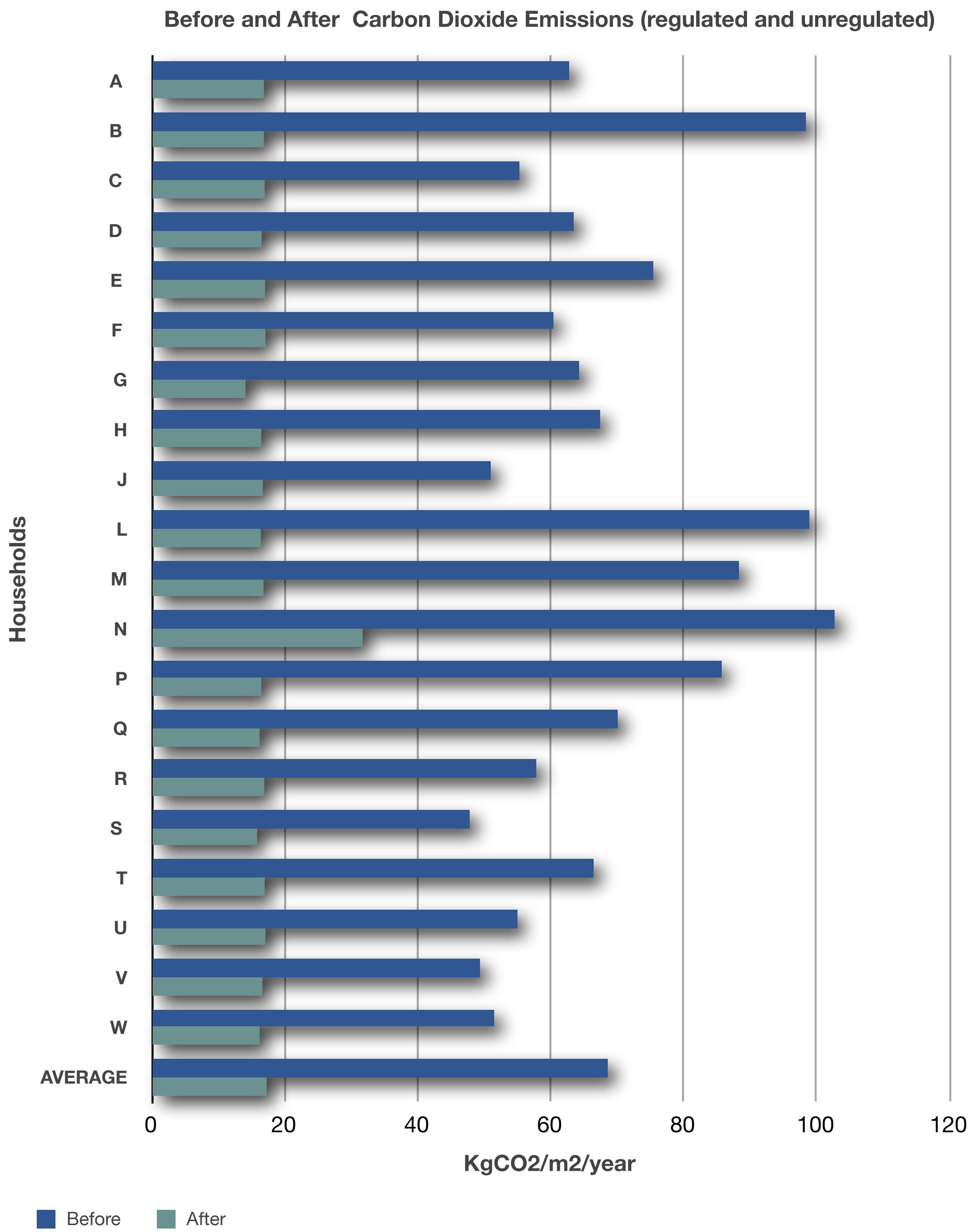


Meeting the 2050 Target

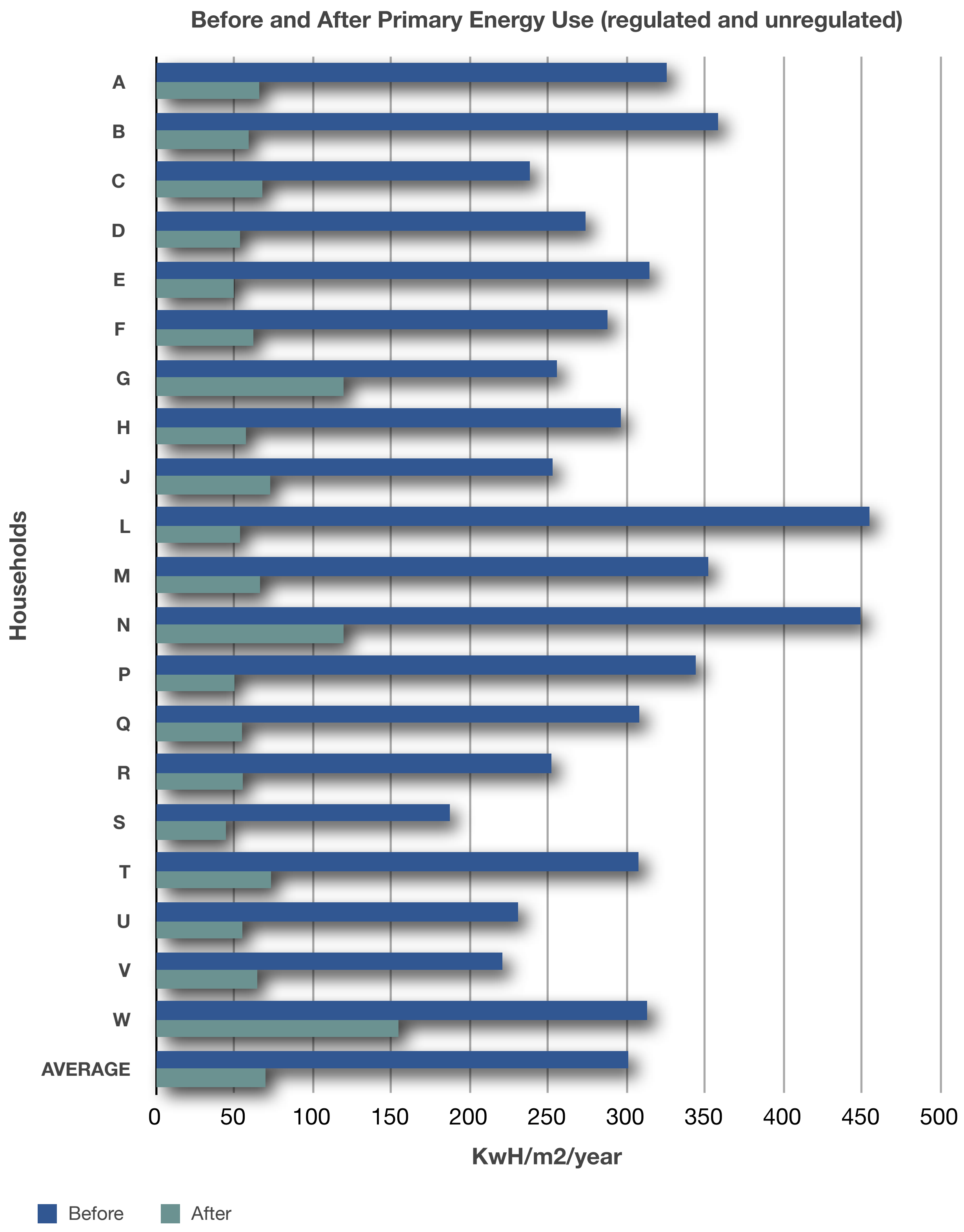
Achieving the target

It is possible to meet the full 2050 carbon reduction target in all but two of the properties examined - with these two properties still able to meet either the carbon or primary energy targets. To achieve the overall emissions reduction and primary energy targets - which covers both regulated and unregulated emissions - it has been necessary to achieve an average SAP rating of 92.





If all the measures suggested are deployed across these twenty houses, total carbon savings will amount to approximately 90 tonnes of carbon saved per annum for regulated emissions alone - 4.5 tonnes per household per annum. An average saving of 51 $kgCO_2/m^2$/year is made, and an average saving on primary energy of 230 KwH/m^2/year if unregulated emissions such as appliance use are included. Scaling up these savings across whole neighbourhoods and cities would make a significant contribution to the 2050 carbon reduction target - whilst also improving the wellbeing of many residents by removing the risk of excess cold and damp in their homes and further reducing the impact of utility price rises.



There may be some 'comfort takeback' in each of the households after retrofit, which would result in actual savings for heating energy being reduced. However, because so many of the homes appear to be under-heated at present, and because so many of the residents take a keen interest in environmental issues, it is equally possible that they will take the opportunity in their new super-insulated homes to use less heating energy than assumed by SAP and still have much more comfortable and healthy internal environments. Also, since heating demand has been reduced to a very large degree, it is at such a low level that even if a particular household uses 30% more than predicted, this is not actually much energy in absolute terms. This may prove a useful area for further investigation and monitoring by the Carbon Coop, providing additional support to ensure that savings are maximised and that lessons are learnt for future retrofit projects.

Costs and Financing

The measures proposed have been costed with support from a quantity surveyor. Future development of the assessment calculator will allow proposed combinations of measures to be given budget cost estimates alongside costs for new appliances and non building elements proposed so that householders will be able to make more informed judgements as to which measures they might choose to go ahead with. This study has been primarily around developing the assessment method and suite of proposals to achieve the 2050 target. From work already carried out we would estimate the shortfall between money saved in utilities and servicing a loan to pay for the costs of the measures proposed would be in the region of 20 - 30%. However more than 60% carbon savings can be achieved for a "standard occupant" and cover the costs of the works as long as the interest rate is sufficiently low. What this study has revealed is that very few of the "early adopters" are standard occupiers, and they would be unable to generate more than a small percentage of the works costs from any further savings in their utility bills.

Implications and Next Steps

Whole House Assessment Methodology

Specification issues

The methodology discussed earlier has meant that there has been a process of comparing different measures to get the optimal carbon saving and to maximise the cost effectiveness of the measures. The tool is such that we have been able to compare different pieces of technology. In some cases are measures regarded as 'standard parts' in retrofit and low energy building appear to have limited effectiveness according to SAP. Despite repeated checking of the calculations against the SAP manual it has not been possible to find calculation errors in these findings. This either means that in some areas there are greater limitations with the SAP method than others, or that this is in fact true.

MVHR

The energy to run fans is generally assumed to be offset by the energy saving from heat recovered from outgoing air. When compared in the SAP model with natural ventilation this is found not to be the case, despite the air change rates being higher in the natural ventilation model than the MVHR one. This is ameliorated in part if manufacturer's figures are used rather than SAP defaults, but it is by no means clear cut. Given the cost of fitting such a unit, this has led us to omit MVHR from many of our proposed measures. This warrants further examination. In our recommendations to residents we have suggested passive stack ventilation systems and assumed that if properly designed these will achieve healthy air change rates as are assumed in SAP when the natural ventilation option is modelled. This in itself probably also needs further work.

Solar Thermal

There have been many studies of solar thermal recently that have suggested that it has a very long payback period, up to 25 years. This has been confirmed in our findings, despite the experience of URBED's other projects involving solar heating which have suggested high levels of effectiveness when combined with biomass. We have confirmed within the calculations that it is effective in combination with biomass and also when compared with electric water heating.

Air tightness

Setting the air tightness to 5 cu.m/sq.m./hr at 50 Pascals has had a very beneficial effect on the model. It was much less marked between 5cu.m and 3cu.m. which is fortunate given the difficulties of achieving the latter air tightness in existing housing.

Low Energy Lighting

Low energy lighting in some conditions has a detrimental effect on SAP, CO_2 and primary energy targets due to the loss of internal gains. This may require further investigation.

Heating Controls

Setting the heating from just timer and thermostat to zone control as well has a marked effect. Given the high levels of insulation once the retrofit has been carried out, and based on the findings of post occupancy work on other URBED retrofits, we would question whether this is really the case. For example, zone controls make little difference in a small house that has been well insulated as only a small amount of heat is needed anywhere within the envelope for the whole house to benefit. This is an area for further research and development.

Appliances

Perhaps the overriding finding has been that when including the unregulated (appliance and cooking) emissions has been that it is impossible to meet the target without some form of renewable generation. Given the nature of the approach, i.e. individual properties, the only renewable generation available in most cases has been photovoltaic electricity. So effective is this, that were we to maximise the PV installation on some of the properties in combination with the other fabric measures we would be able to achieve "zero carbon" performance.

From a simple cost point of view, it would suggest that some of the more expensive measures could be substituted for more photo voltaic installation and in the early years of the retrofit market this may indeed be an appropriate method. However this would mean continued burning of fossil fuels and rising energy costs therefore it is always better to adopt a demand reduction approach and so we have kept to this approach for this study. That said, there are implications for the Carbon Co-op business model in the early years of it's development before the economies of scale for retrofit have led to the same cost reductions as those seen for photo-voltaic installations.

Poor state of much existing housing - health perhaps as much a priority as carbon?

As has been mentioned earlier many of the properties were suffering from high humidity levels causing damage to buildings and occupants. Whilst not a surprise in itself, the high proportion was. This reinforces the view that retrofit should not solely be concerned with reduction of emissions, it should also concern itself with improving quality of life and comfort.

Mismatch between model and actual - how to overcome uncertainty?

Many professionals in the retrofit field have expressed concern about the lack of reliability of the SAP model. However trying to standardise how energy is used in buildings is never going to be an exact science. Monitoring work carried out on other URBED retrofit projects has suggested that the variability, for space heating demand at least, is not unreasonable in super-insulated homes.

One of the aims of this project was to develop more reliable model, looking at all energy use in the property. The variations in people's awareness of their own energy use has made this very difficult and we have instead used add-ons to the SAP model to create a more standard estimate of appliance use and set this next to the householders actual bills merely as a check so that in our narrative to the householder and indeed to our own assumptions. This ensures we are not going to be assuming delivery of cuts when they have already been made. For example, display energy meters have been studied in use and shown to increase people's awareness of appliance use leading to reduced energy use. It would appear that many of these householders are already aware of their appliance use and very thorough in ensuring items are not left running unnecessarily. The Carbon Co-op already has experience with energy meters and more developed equipment that measures individual socket use. This would seem to be an ideal area for the Carbon Coop to develop, where a great deal of very useful work could be done to try and establish more reliable methodologies for more reliable estimation of appliance use and how to cut it and reduce the error margin. This would allow more reliable prediction of retrofit outcomes.

Householder's Next Steps

Many of the households surveyed as part of this report are suffering with poor internal conditions. For these reason, alongside the suggested measures to take the properties to the 80% target, URBED will make informal recommendations to the occupants about how they can improve their internal environment and energy use through smaller and less expensive 'first steps'. These are likely to include improved heating controls, such as programmers and timers and remote controlled or programmable TRVs , as well as suggestions for improved ventilation and reduced internal humidity - such as new clothes drying arrangements or improved trickle ventilation.

The reports produced as part of this project show how to get the whole house to the 2050 target, however there is a finer grain level of work which needs to be done. This is beyond the scope of this piece of work and for now the description of these early wins will be a narrative one. However our hope is that some of the householders will be sufficiently interested to take these household assessments forward and develop them into whole house action plans. These would sequence the measures in a way most appropriate to the current occupant. This sequencing would be based on those residents desires and is likely to include other trigger points in the use of the home, such as refurbishment of some rooms or re-roofing. It would also be based on access to capital. In many cases these early stages may be eligible for Green Deal support, in others householders may be able to extend their existing mortgages and so have work done outside the confines of the Green Deal at a lower cost of finance. It would obviously be of great value if some decided to have the full package done now to broaden the body of knowledge of the most effective ways of achieving what is a very challenging energy reduction target.

Importance of monitoring

The Carbon Co-op is extremely well placed to be able to deliver on what is the biggest missing part in the retrofit jigsaw : reliable information on effectiveness of measures in use. The importance of ongoing monitoring cannot be underestimated. The claims for the effectiveness of many measures are based on testing in laboratory conditions which are free from the vagaries of users and installers and the myriad variations on the situations into which these products are put. Whilst some benefits of ongoing monitoring will accrue to residents as it will enable them to make best use of the measures installed, this is unlikely to cover the cost. Proper monitoring requires investment in time, expertise and equipment. External funding sources should be sought to assist in this regard.

The target

The assumption on SAP aspirations for household refurbishment have been described in many quarters as a high B, equivalent to a rating of about 85. When the $17kgCO_2/m^2/year$ is used as the target for the whole house energy use this rises to between 91 and 96. This divergence has implications for policy both immediately for the Carbon Co-op but also more widely for how the residential sector does its share of the emissions reduction trajectory shown earlier. Further research and development is required here.

Householder Report

The individual household assessment reports produced as part of this study are pilot versions. Feedback should be sought by the Carbon Coop on the format for these. As one of the first formal engagements with residents on whole house retrofit they are a crucial tool for communication. They need to convey lots of information without being overwhelming or unintelligible. (The current template is included as an appendix).

Carbon Coop

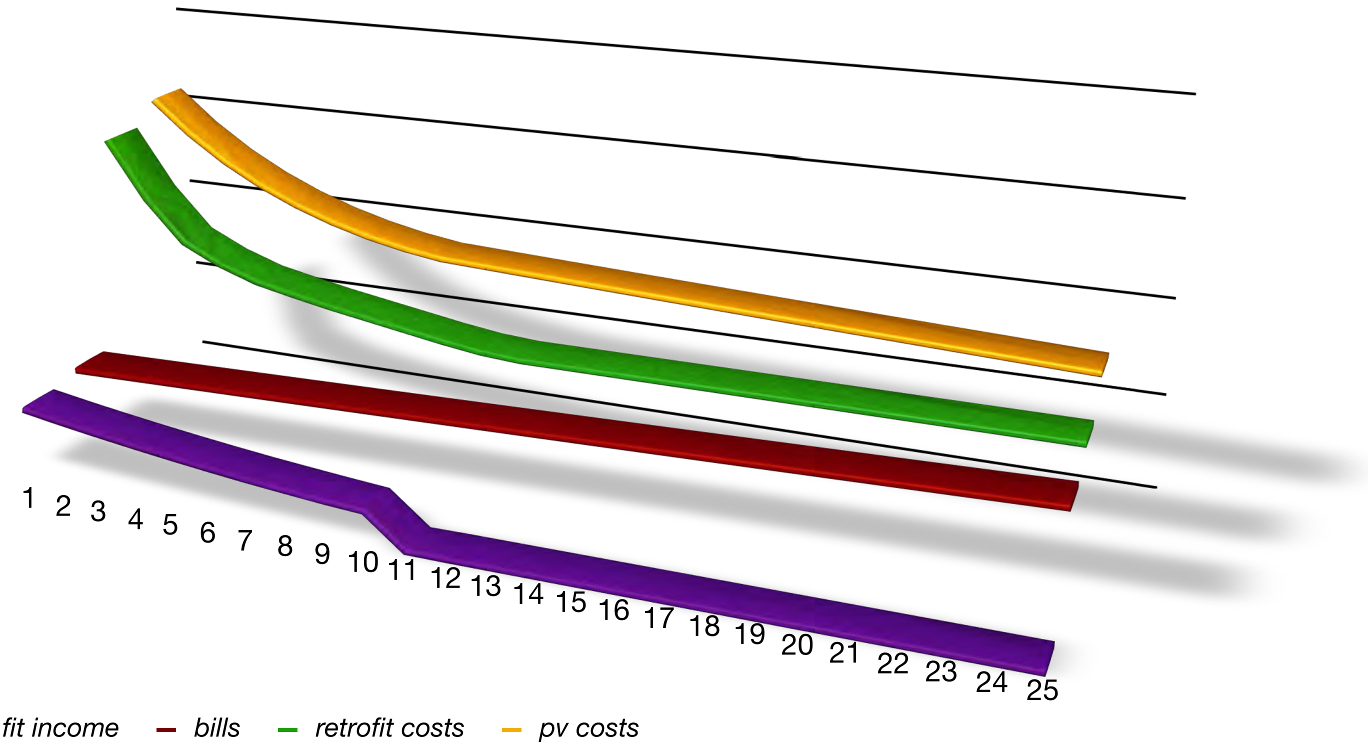
Nature of 'early adopters'

One of the biggest issues arising from this report is the mismatch between the Green Deal's anticipated repayment method and the nature of the early adopters who are most likely to take up the measures.

In most of the business models for the Green Deal the assumption is that early adopters will lead the way. Whilst we are reasonably confident that some of the innovators, for whom reduced bills is only one objective among many, will carry out whole house retrofits, without greater levels of subsidy there is a risk that the Green Deal will fail to make a sufficient impact to start to deliver the very considerable need for carbon reductions demanded in the work of people like the Tyndall Centre.

Domestic property valuation does not yet value the kinds of measures discussed in this report, although there is evidence of slow change as has been proven in the attractiveness of measures such as double glazing. If the housing market catches up with the idea of the whole cost of occupation of the property affecting its value this may assist in closing the gap. For this logic to be of relevance to rented properties, most landlords may need to be involved in the provision of energy so that finance costs could be directly offset against lower utility bills. There is already evidence that in commercial property 'A' rated properties are seen as valuable in some markets. A shift needs to happen for this to cross into the domestic sector.

The Community Green Deal finance model seeks to create a funding arrangement that effectively defers the higher cost of retrofits of the early adopters by cross subsidising from renewable energy incentives. However since this model was devised those incentives have contracted to the point that this no longer works as well.



It is highly likely that as the retrofit market picks up the costs will reduce considerably. However for the market to take off more people need to enter it so funding vehicles are needed that can assist those early adopters until the gap between costs and savings has closed sufficiently.

The Superhomes Network has proved that there is a body of people prepared to carry out these works for other reasons [12]. Organisations like the Carbon Co-op are well placed to find more of these people who will undertake whole house retrofits because a) it has to be done now to enable others to learn how to do it, b) it will massively reduce their vulnerability to future utility price rises, c) it will make their home a lot more comfortable and a lot healthier, d) it will eventually have an effect on it's value.

Position on grid de-carbonisation?

The emissions reduction target used in this project has been taken as whole house energy use, however there has been a relaxation in the definition of carbon neutral that has created an impression that such targets only apply to regulated energy use (with ref to 2016 Building Regulations). This has been supported by the assumption that decarbonisation of the grid will allow household emissions reduction to reduce with no net reduction in electricity use in the house itself. The slow growth of renewables in the UK compared to target suggests that this may be over-optimistic. In the absence of updated targets omitting unregulated energy use we have kept to a target including all household energy use.

The retrofit measures proposed in this document take a current grid electricity carbon intensity as a result of using SAP. Therefore the outturn carbon emissions for these properties are in today's numbers. Given the Tyndall Centre's graphs suggest that very considerable carbon reductions are required now we feel that this is an appropriate direction to take. The time-scale is such that as the grid is decarbonised, gas boilers will be able to replaced with what by then will be less carbon intensive forms of heating. Given the slow pace of grid decarbonisation currently, were we to have adopted electric forms of heating such as heat pumps now we would have both failed to save the residents any money but also deferred carbon savings to a date that may be too late.

12 www.superhomes.org.uk

Appendix:

A: TEMPLATE HOUSEHOLDER REPORT

HOUSEHOLD ENERGY REPORT

NAME	XXXX
	XXXX
ADDRESS	XXXX
	XXXX
	XXXX
TYPE	SEMI DETACHED
DATE	XXXX

THE PROJECT

Carbon Co-op has appointed URBED to carry out twenty whole house energy assessments of properties within Greater Manchester and to create a generic energy performance tool to help achieve an 80% carbon reduction.

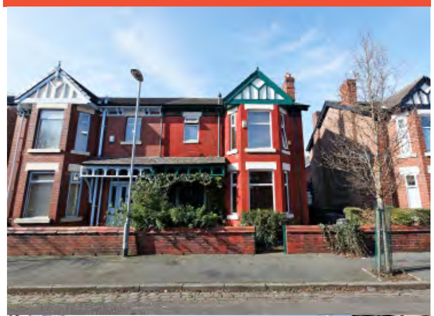
THE METHODOLOGY

The Standard Assessment Procedure (SAP) was used to assess the energy performance of each house.

Each house was visited to gather the required information and data. The house dimensions were measured, photos were taken and the occupants were interviewed. This provided details of the heating system, occupancy habits, appliances' consumption and other matters related to house construction or energy efficiency.

After gathering all the required data, the current performance of the house was assessed. A standard SAP assessment, covering only 'regulated emissions' was produced, as well as an estimate of energy use and carbon dioxide emissions linked to unregulated uses. A series of measures were then proposed in order to reach the absolute 2050 target, reducing carbon emissions by 80% on average on a notional 1990 baseline - taking total carbon emissions to less than 17kgCO_2/m^2/year and primary energy to less than 120 KwH/m^2/year.

PROPERTY

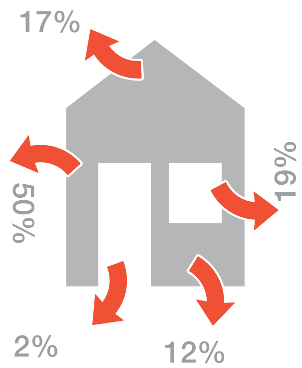


This Household report has been produced by URBED. For further information please contact Charlie Baker

a. URBED, Fifth Floor, 10 Little Lever St
M1 1HR, Manchester
t. 0161 200 5500 e. charlie@urbed.coop

CURRENT PERFORMANCE

HEAT LOSSES

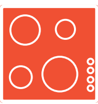


This is the proportion of heat lost from the inside of your house to the external environment through the different building surfaces.

LIGHTING, APPLIANCES & COOKING

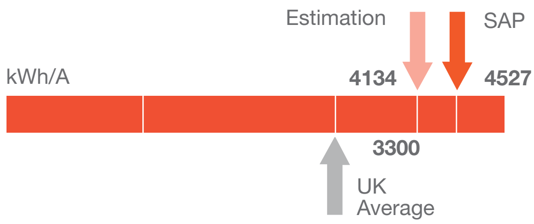
Based on the number and type of lighting fittings, the daylight, and the occupancy, the total energy use for lighting is estimated at 482 kWh annually.

Based on the usage pattern of your appliances, the total energy use for your TVs, laptops, kettles e.t.c. is estimated at 3,213 kWh annually



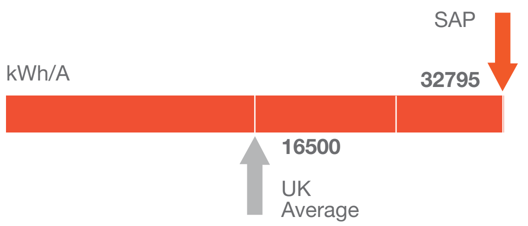
The energy required for cooking which is based on the occupancy and the type of cooker, is estimated at 440 kWh annually.

ELECTRICITY USE



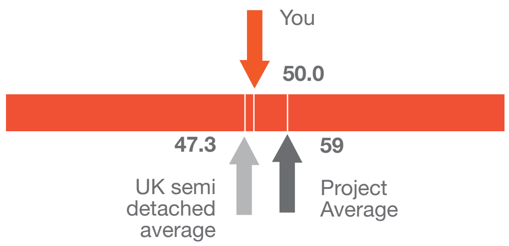
The SAP figure is the estimate of your electricity use from the SAP tool. The Estimation number is based on the answers you gave to the occupant questionnaire. Unfortunately we were unable to extract actual use data as you provided us with an overall billing associated with both gas and electricity.

HEATING & HOT WATER USE



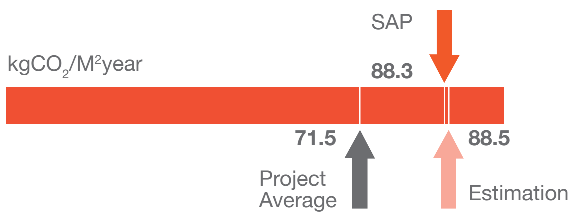
This is the estimate of your heating and hot water energy use from SAP. Unfortunately we were unable to extract actual use data as you provided us with an overall billing associated with both gas and electricity.

SAP RATING



The SAP rating is based on the energy costs for space and water heating, ventilation and lighting. The higher the costs are the lower the SAP rating. A comparison is made with the rest of the homes in this project and the average UK semi-detached rating.

DWELLING CO_2 EMISSIONS



This is the estimated total existing carbon dioxide emissions from your dwelling. The Estimation figure is based on the answers you gave to the questionnaire. The SAP figure is based on generic assumptions in SAP.

MEASURES

The table below outlines the potential measure which could be implemented to achieve the 80% carbon reduction target. Costs are provided for budget guidance only, based on best available information from a quantity surveyor. They are not formal quotes, and actual costs may vary.

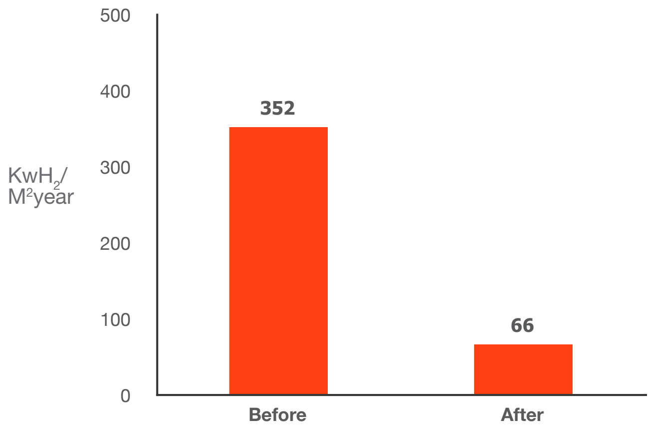
MEASURES	BENEFITS	NOTES

PROPOSED PERFORMANCE

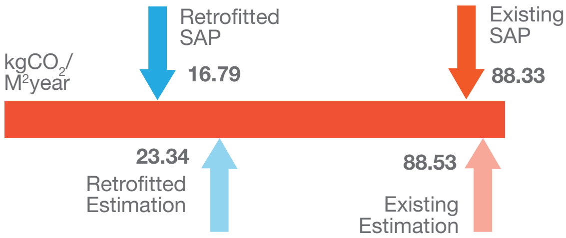
REACHING THE 2050 TARGET

If all of the measures suggested on the previous page are deployed, it will be possible for your home to meet the full 2050 carbon emissions reduction target. However, it may prove necessary to install these measures in phases, and advice should be taken as to the best order in which to do this. It may also be possible to make greater improvements by changing the way you use the heating systems and appliances in your home. The Carbon Coop can provide further advice and guidance on this.

DWELLING PRIMARY ENERGY USE

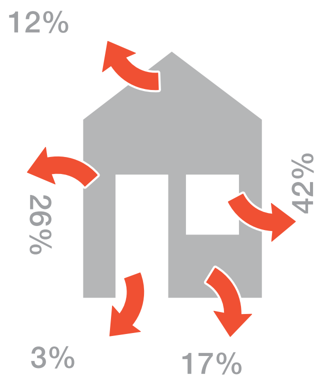


DWELLING CO2 EMISSIONS



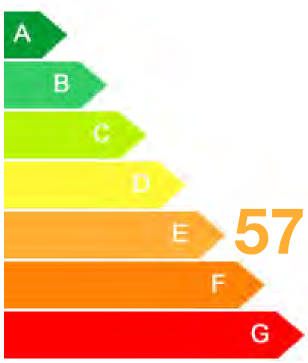
The retrofit measures suggested reduce the dwelling primary energy use and drop your household total carbon emissions by 81% as calculated by SAP and 74% when compared with your occupancy questionnaire results.

HEAT LOSSES



PERFORMANCE SUMMARY

EXISTING



PROPOSED