Analysis for WWF and UK-GBC: achieving minimum EPC standards in housing

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parity projects

ABOUT PARITY PROJECTS

Parity is an award-winning provider of environmental and energy solutions to the residential building sector. We help our customers identify the most effective ways to reduce the energy impact of their properties.

The backbone of our work is the use of computer modelling (CROHM and Home Energy Masterplan) to identify the most appropriate measures for properties based on cost estimates and building physics. Parity also provides services such as training and building monitoring.

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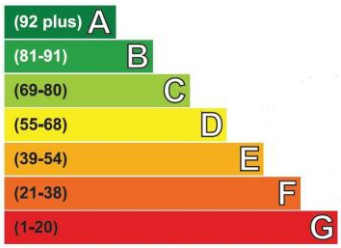
1 Executive Summary

Under the Energy Act 2011, privately rented homes will need to meet a minimum standard of energy efficiency, expected to be an EPC rating of E. In this context, WWF and UK-GBC have commissioned this report, which attempts to describe in detail the modelling of a number of energy retrofit options on a sample of F and G rated domestic homes from across the UK.



General Approach

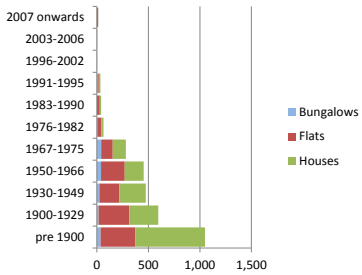
An anonymised and cross-tenure sample of just over 3,000 homes modelled as being rated in EPC bands F and G has been analysed in this report. We aimed to maximise the sample size in accordance with one of the analysis aims of investigating whether any homes could not be upgraded to band E with conventional energy saving measures.

In section 3 the characteristics of these properties have been investigated. In section 4 a wide range of costed upgrade options for these homes is identified. Section 5 presents our modelling of these upgrade options with the aim of reaching minimum SAP 39 (EPC band E) across our sample. Sections 5.1 and 5.2 show how all properties in our sample could be successfully upgraded to band E even when the applicable measures were restricted to 'planning friendly' measures that would not affect the external appearance of the property.

Housing Sample

A sample of properties has been used for the analysis based on the property portfolio available from previous analyses. We have calculated SAP ratings in bands F and G (i.e. SAP score of 38 or lower) for each property in the sample.

The characteristics of homes in our sample are investigated further in section 3.2 and this analysis shows that these homes tend to be low rated as a result of a number of inefficient characteristics in the same property or because of expensive heating fuels such as on-peak electricity or LPG.



Count of sample properties by age band (from Figure 3)

Options modelling

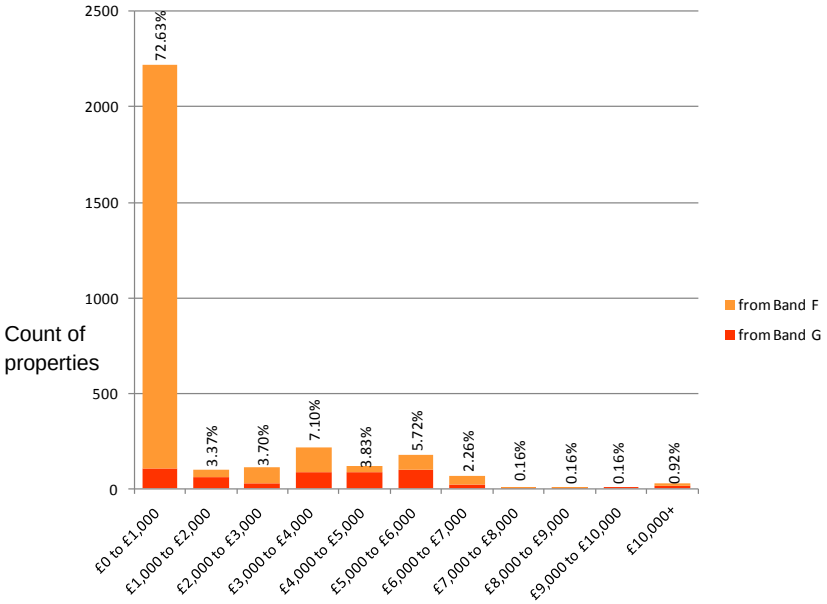
The full set of measures identified in properties in the sample is summarised in section 4, with detail provided in a spreadsheet that accompanies this report. The most important measures (measures with largest combined effect across the sample) are highlighted.

In general we note that this section includes far more measure types than usually apply in our stock assessments for individual clients. The main reason for this large number of applicable measures appears to be the relatively large number of relatively unusual (and often inefficient / expensive to run) heating systems in the sample.

Minimum SAP E modelling: no restrictions on measure choice

In section 5.1 we present the results of applying compatible measures in order of cost effect[1] (most cost effective first) to estimate the level of investment required to achieve a minimum SAP target of 39 (SAP band E). The full compatible measure set used is listed in Appendix B.

All properties were able to achieve a SAP score of 39 or above (SAP band E), at an average cost of **£1,421** per property. The calculated average fuel bill saving per homes is £409 per year. Over 70% of the 517 G rated properties in our sample are modelled as reaching the target at a cost of less than £5,000, and over 80% of the 2,504 F rated properties can reach the target at a cost of less than £1,000. Only 9 properties in our sample are modelled as requiring more than £10,000 to reach the target. The chart to the right is a copy of Figure 10 which illustrates the spread of costs.



Minimum SAP E modelling: 'Planning friendly' measures only

In section 5.2 we present the results of a second analysis, in which we apply compatible measures in order of cost effect (most cost effective first) but excluding measures likely to make a difference to the external appearance of the dwelling (specifically solar panels, glazing upgrade, solid wall insulation).

Again, all properties were able to achieve a SAP score of 39 or above (SAP band E), this time at an average cost of **£1,345** per property. The target was reached at lower cost using a smaller selection of measures because the 'planning unfriendly' measures tend to result in larger energy savings per measure. When using only 'planning friendly' measures the target SAP score is generally exceeded by a smaller amount when reached.

The spread of costs required to reach the target using these measures is very similar to the spread using the unrestricted measure set considered in the previous section.

The calculated average fuel bill saving per home for this analysis is £408 per year.

[1] Based on cost per SAP point increase

Conclusions

We find that every dwelling in our sample can achieve a SAP target of EPC band E relatively easily, at a relatively low average cost of around £1,400 per property, and without resorting to unconventional measures such as super-insulation beyond building regulation standards. The investment results in an average calculated fuel bill saving of about £410 per year. The average cost hides some detail: while over 70% of the sample can reach the target for less than £1000, an average G rated property requires about £3,500 to reach the target. We also find that every dwelling in our sample can achieve this target without measures that may be prevented by planning restrictions because they affect the external appearance of the dwelling.

The cost to reach band E is lower than other studies, and this may be a reflection of our method of applying measures in strict order of decreasing cost effect, and including additional measures that we have applied that are not used in the standard on EPC methodology[2].

[2] For example, a measure to add the optional specific boiler model rather than generic boiler category tends to result in a SAP score improvement.

2 Introduction

This report is an overview of the analysis conducted on a sample of 'low SAP' (G and F rated) properties for WWF and UK-GBC. Parity has used its Carbon Reduction Options for Housing Managers (CROHM) stock assessment tool to model the energy use of the housing sample, based on anonymised data in Parity's previous assessment portfolio.

This report presents the modelling exercise conducted in accordance with our brief from WWF and UK-GBC. Our brief has been to:

- **Present an estimated carbon/SAP baseline for the sample of properties**
  A 'snapshot' baseline is presented here. The anonymised data, in combination with appropriate assumptions, has been used in the model to calculate these figures. We also provide some stock profiling information later in section 3
  This is presented in section 3 pp.8-10

- **Identify and evaluate potential energy/CO_2 saving/SAP improvement initiatives**
  The data used to calculate the baseline as above was used to model the energy use of the properties sampled for WWF and UK-GBC with the aim of showing the potential for improving the energy performance. The model was used to identify potential for individual energy saving measures within the housing sample, and to provide an estimated cost and carbon saving estimate and prediction of SAP. This has been used to provide a cost benefit analysis of each initiative type.
  This is presented in section 4 pp.12-18

- **Identify and model potential investment scenarios**
  In these sections we have investigated the results of applying compatible measures in order of cost effect (most cost effective first) to estimate the level of investment required to achieve a minimum SAP targets of 39 (SAP band E)
  - without restriction on the measures selected (section 5.1)
  - using only 'planning friendly' measures that do not affect the external appearance of a dwelling (section 5.2)

  This is presented in section 5 pp.19-Error! Bookmark not defined.

- **Case studies**
  Presented in section 6 pp.25-30

A summary of the analysis results is presented in a spreadsheet that accompanies this report: this spreadsheet is the backbone of this report and of our analysis. It includes a list and summary analysis of the various energy saving measures that the data indicates are possible in the properties sampled for WWF and UK-GBC. For each measure, a number of summary figures are provided including average estimated installation cost, number of possible measures, estimated carbon improvement, and average expected SAP improvement. We expect this table to be as useful as this written report in decision-making.

3 Baseline results and options analysis

A sample of properties based on the property portfolio available to Parity Projects from previous analyses has been used for the analysis. We have calculated SAP ratings in bands F and G (i.e. SAP score of 38 or lower) for each property in the sample. Note that only data points where Parity Projects holds appropriate licences to use the data in this way were used and the addresses of all data points were removed before our analysis, with postcodes changed to provide regional information only.

We aimed to maximise the sample size in accordance with one of the analysis aims of investigating whether any homes could be found that could not be upgraded to band E with conventional energy saving measures. We were unable to restrict the sample to private rented homes as information on private rented tenure was unavailable for most of the sample.

3.1 ESTIMATED CARBON BASELINE AND SAP SCORE

We estimate that the total annual carbon footprint of the F and G rated properties sampled for WWF and UK-GBC is **7.80 tonnes CO_2 per unit**. This compares to the national average of between 3 and 4 tonnes CO_2 per dwelling[3].

For the properties sampled for WWF and UK-GBC our analysis indicates an estimated average SAP 2009 score of **29.4**. The distribution profile of the properties sampled is shown in Figure 1 below and compares well with the profile of F and G rated properties across a typical UK borough as described overleaf.

[3] Our figures are calculated using RdSAP which *excludes* CO_2 from appliance use. National averages *including* appliance use are available (e.g. UK housing fact file 2013). Average proportions of household energy consumed by appliances are also available. In combination an average total per home excluding appliances of around 3.8tCO_2 per home appears to be a fair estimate, but a directly comparable national figure could not be found.

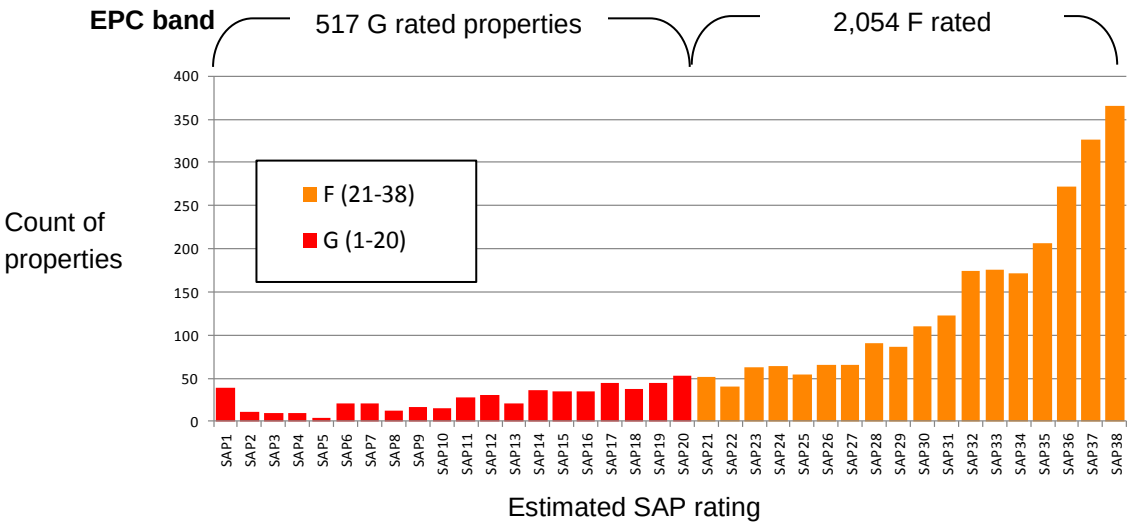


Figure 1: estimated SAP distributions in the analysis sample

The distribution profile presented in Figure 1 relates to a sample of properties specifically selected for their low EPC rating. The profile shows a full range of F and G rated properties, with a large proportion of the properties sampled just below the minimum E target (39 SAP points) and a small but still significant number of properties sitting much further below the target.

The small spike at 1 SAP point is a reflection of this score representing all properties calculated with a SAP score below 1. SAP 1 is an arbitrarily defined minimum to the scale and, although the model allows for scores to be calculated below this point, the RdSAP score as presented on an EPC is restricted to a minimum score of 1.

The SAP profile of our sample shown in Figure 1 (restricted as it is to F and G rated properties only) compares well with the typical distribution pattern of profiles of an entire housing stock. A typical sample of UK housing would have a SAP average of around 60; a typical example profile is provided in Figure 2 below.

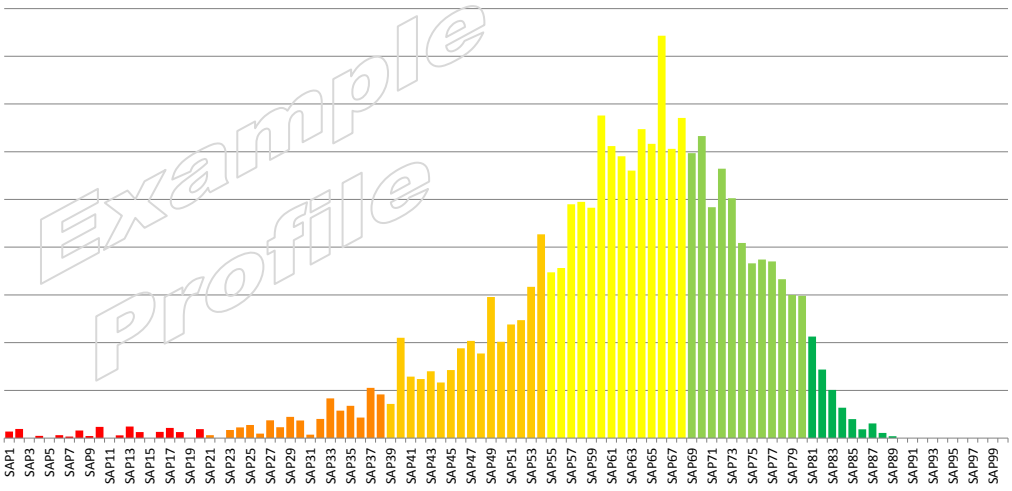


Figure 2: anonymised example profile for housing stock within a mixed UK borough, displaying a relatively normal distribution with large proportion of properties around the average score and a 'tail' of low SAP properties

3.2 HOUSING STOCK PROFILING

As illustrated by Figure 3 below, the housing sample of F and G rated properties appears to include a fair amount of diversity in age, but with a high proportion of properties built before 1930 (55%) and a small proportion of properties built post-1967 (15%). It also includes a small number of post-1990 built homes (2%), which is somewhat surprising given modern building standards. This appears to be generally due to high-cost heating fuels such as on-peak electricity and LPG in these properties.

The stock profiling information in this section is designed to allow comparison of the sample. The data used to produce the charts in this section is provided in the spreadsheet provided with this report.

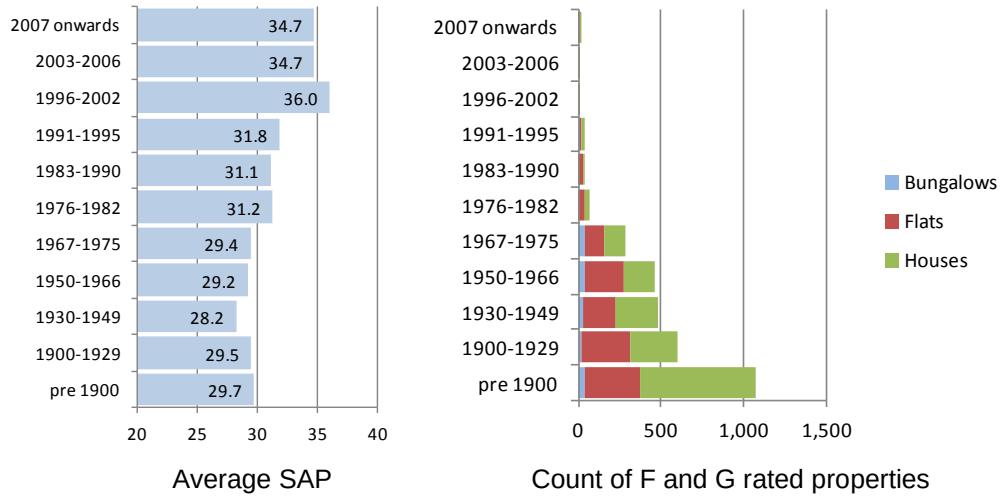


Figure 3: Summary of sampled F and G rated properties for by age: average SAP by age (left chart) and itemised by age category and built form (right chart)

There are a low proportion of houses (52%) in the sampled stock compared with 71% of all properties nationally[4]. Flats account for a higher proportion (42%) of the sample compared with 20% nationally[2], with bungalows accounting for the remaining properties (6%). Being so few, maisonettes have been grouped with flats in Figure 3.

Overleaf we have presented the wall type (Figure 4), roof type (Figure 5) and main heating fuel (Figure 6) of the housing sample.

[4] 2013 Housing Energy Fact File

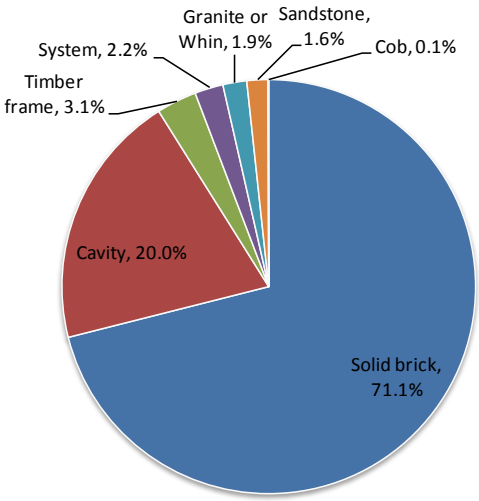


Figure 4: Summary of the housing sample by main wall type

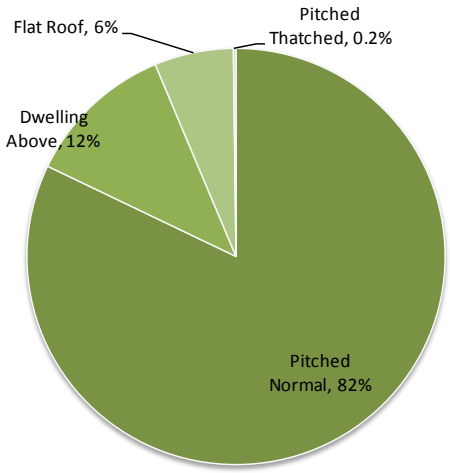


Figure 5: Summary of the housing sample by main roof type

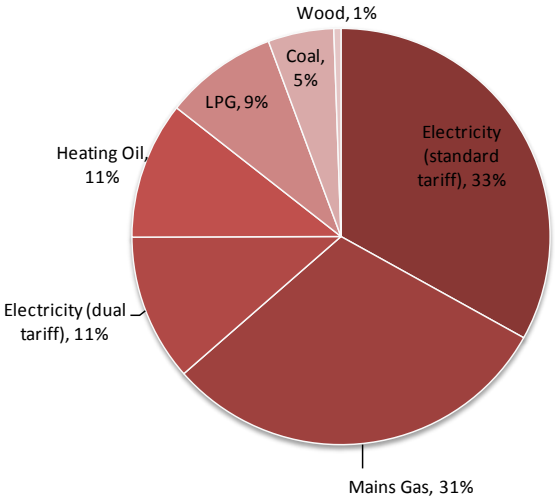


Figure 6: Summary of the housing sample by main heating fuel

4 Options analysis

This section is based on the computer options modelling for the sampled housing stock. A more complete summary (in tabular format) is provided in the accompanying spreadsheet to allow readers of the report to investigate our findings in more detail if required.

In our options analysis we have broken down some of the measures based on the current characteristics of the building. For example, we have considered boiler replacement for existing boilers within various efficiency bands as different measures. The range of measures considered is provided in Appendix B, and the costs used are provided in Appendix D. Note that the measures used include measures not included as recommendations on an Energy Performance Certificate.

In general we note that the options analysis for the sample of F and G rated homes contains far more measures than usually apply in our stock assessments for individual clients. This appears to be because of the relatively large number of unusual (often inefficient and/or expensive to run) heating systems in the sample.

4.1 OPTIONS ANALYSIS SUMMARY

Many measures with financial paybacks shorter than 5 years (£100 per SAP or better per dwelling) remain to be installed on the sampled F and G rated properties. The most notable measures in this cost-effect band are:

Measures with shortest paybacks 0-5 years (£100 /SAP point or better)

- **Add actual boiler references** (925 dwellings, ~4 SAP points per dwelling)
  Usually the data for specific boilers contains greater efficiencies than the default efficiencies by boiler type. This may seem like a technicality, but many EPCs may be F rated because generic boiler information has been selected rather than specific model data, resulting in a conservatively low calculation result.
- **Switch tariff from single to dual** (524 dwellings, ~12.5 SAP points per dwelling)
  The initiative has been applied to 524 homes with hot water from immersion heaters with a single rate tariff.
- Add 300mm insulation to **empty lofts** (1,102 dwellings, ~13 SAP points per dwelling)
- **Add full controls** (Thermostatic Radiator Valves, room thermostat) from programmer only (403 dwellings, ~7.5 SAP point per dwelling)
- **Fit baffles to block open chimneys when not in use** (751 dwellings, ~2.0 SAP points per dwelling)
- **Replace bottled LPG with bulk LPG** (94 dwellings, ~11.1 SAP points per dwelling)
- **Upgrade to full zone controls** (Thermostatic Radiator Valves, room thermostat) from single programmer only (277 dwellings, ~12.4 SAP points per dwelling)
- **Cavity wall insulation** pre-1976 wall (389 dwellings, ~1.5 SAP points per dwelling)
- **Remove secondary non-portable electric heaters** (329 dwellings, ~3.4 SAP points per dwelling)
- **Draught-proof** all doors and windows (1,733 dwellings, ~1.0 SAP points per dwelling)

- **Replace electric heaters** with A rated combi system, where gas is available at the property (336 dwellings, ~4.3 SAP points per dwelling)
- **Replace electric boiler and electric heaters** (where gas distance is unknown) with fan storage heaters (173 dwellings, ~25-30 SAP point per dwelling)

Measures with financial paybacks in the order of 5 to 20 years (£100-£500 per SAP point) presents a number of additional significant opportunities for improvement, notably:

Measures with paybacks 5-20 years (£100 - £500 /SAP point or better)

- Upgrade to **full zone controls** (Thermostatic Radiator Valves, programmer) (767 dwellings, ~5 SAP points per dwelling)
- **Decommission Electric ceiling heaters and Electricaire systems**, replace with gas combi (gas near or in property) (67 dwellings, ~41-43 SAP points per dwelling)
- **Upgrade gas room heaters** to new central heating with combi (95 dwellings, ~25.2 SAP points per dwelling)
- **Replace electric heaters** with A rated combi system where allowed by local gas supply (483 dwellings, 37-38 SAP points per dwelling)
- **Replace Storage Heaters** with A rated combi system (287 dwellings, ~25 SAP points per dwelling)
- **Replace electric boiler** with A rated combi system, Gas near property (82 dwellings, ~40.7 SAP points per dwelling)
- Upgrade regular **gas boiler rated C and below to A rated combi** (649 dwellings, 10-16 SAP points per dwelling)
- Upgrade **gas combi boilers rated C and below to A rated combi** (163 dwellings, 4-13 SAP points per dwelling)
- **Upgrade G rated LPG boiler** to A rated LPG combi (166 dwellings, ~21.6 SAP points per dwelling)
- **Upgrade solid fuel room heaters** to new oil central heating with combi (74 dwellings, ~30.6 SAP points per dwelling)
- **Upgrade F rated oil boiler and F equivalent solid fuel boiler** to A rated oil combi (334 dwellings, 14-16.0 SAP points per dwelling)
- Upgrade modern slimline storage heaters to **fan storage heaters** (199 dwellings, ~5.8 SAP points per dwelling)
- Retrofit **WWHRS** in suitable shower or shower and bath rooms (1,459 dwellings, ~5.4 SAP points per dwelling)
- Upgrade remaining **inefficient lighting** (2,672 dwellings, ~0.8 SAP points per dwelling)
- **Insulate 1900-1966 timber frame** walls internally (70 dwellings, ~13.9 SAP points per dwelling)
- Fill and add external **insulation to empty pre 1976 cavity walls** (386 dwellings, ~15.6 SAP points per dwelling)
- **Insulate pre 1976 solid walls** externally (2,135 dwellings, ~16.4 SAP points per dwelling)
- **Insulate 1900-1966 stone walls** externally (90 dwellings, ~20.2 SAP points per dwelling)

The most notable measures with financial paybacks in the order of 20 to 40 years (£500-£1000 per SAP per dwelling) are:

Measures with paybacks 20-40 years (£500-£1,000 /SAP point)

- Externally **insulate exposed floor** (423 dwellings, ~3.6 SAP points per dwelling)
- Add 50mm or equivalent **insulation to pre 1996 solid and suspended timber floors** (1,634 dwellings, ~2 SAP points per dwelling)
  Including properties where floor insulation is unknown and assumed to be as-built.
- **Replace single glazing** with new double glazing (1,248 dwellings, ~3.3 SAP points per dwelling)
- Install **solar hot water panels** where existing system includes hot water cylinder (1,237 dwellings, ~5.0 SAP points per dwelling)
- **Solar PV** panels on all available roofs (1,486 dwellings, 5-6 SAP points per dwelling)
  South facing roofs are most cost effective, but SE/SW and E/W facing roofs are relatively close

The options above do not cover the alternate options considered such as upgrading to heat pumps or upgrading hot water cylinders (given that combi upgrades may render these redundant). Air source heat pumps options tend to result in larger SAP savings than replacing with conventional if efficient boilers, but they are also more costly which means they tend to have longer pay back periods. CO_2 savings also tend to be relatively much smaller or negative because of the fuel switching element.

The paragraphs above deal with fuel bill saving measures which will reduce a property's fuel bill and improve the SAP rating as used to produce an EPC band. Our detailed analysis as presented in the spreadsheet that accompanies this report also presents cost effect by carbon saving. The results are broadly similar, with the exception of fuel switching measures. For example, off-peak electricity is broadly the same price as gas, but much more CO_2 intensive, so switching from off-peak electricity to gas results in a much more dramatic CO_2 saving than fuel bill/SAP saving.

4.2 APPLICABLE IMPROVEMENT MEASURES

As expected, the G (1-20 SAP points) and F (21-38 SAP points) rated properties sampled for this report are characterised by features that result in poor energy efficiency and higher than typical energy bills. In this section we have tried to show the fuel bill saving measures that apply to the properties in these two bands.

Our approach in this section has been to present two charts for the G rated and F rated properties in the sample showing the proportions of different types of fuel bill saving measures that apply to properties in the two bands. This allows consideration of and comparison between the measures applicable to properties in these two bands.

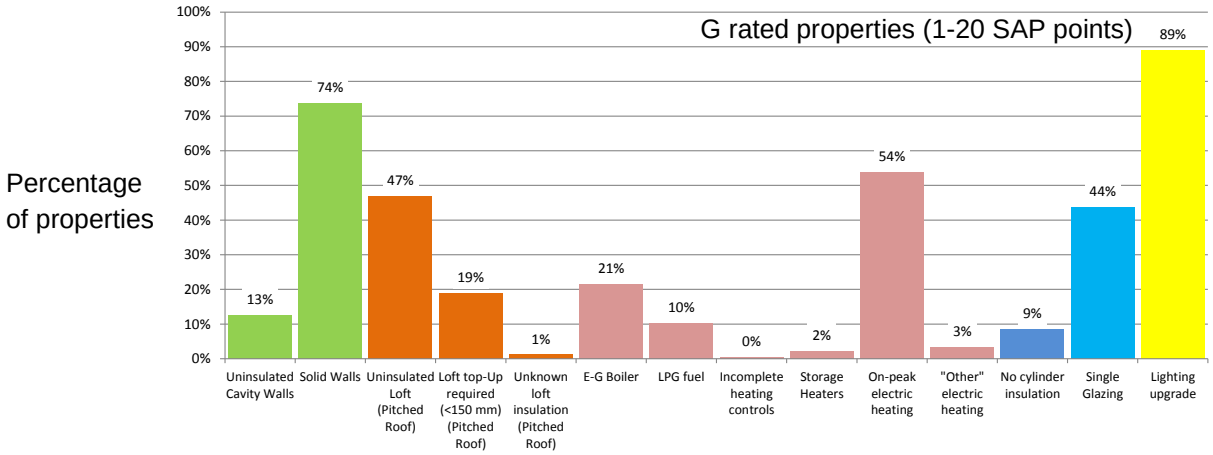


Figure 7: Chart showing measure applicability profile for G rated homes in the sample

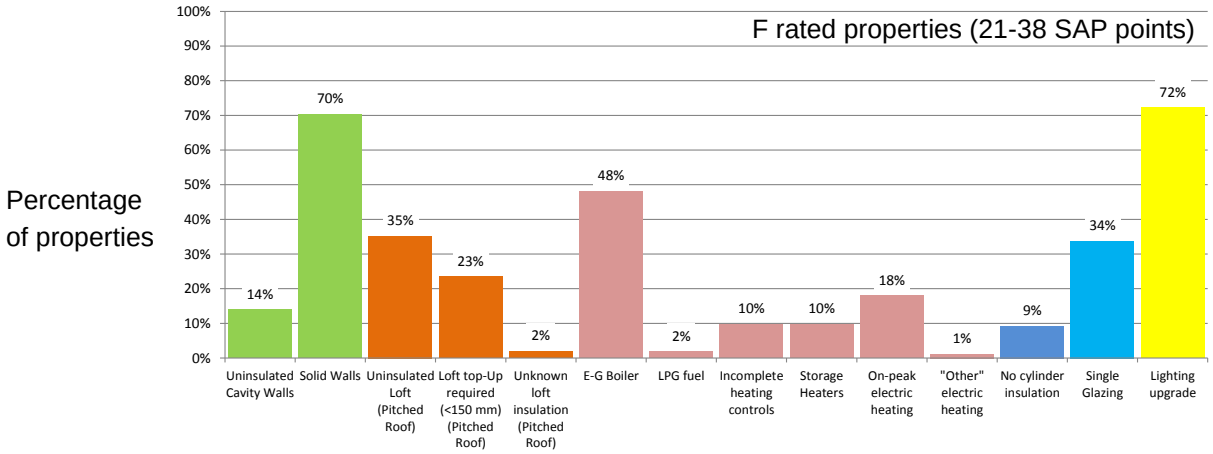


Figure 8: Chart showing measure applicability profile for F rated homes in the sample

Commentary

With the exception of lighting, which our experience shows to have uniformly high applicability across stock assessments for a variety of clients, the figures above show that proportionally many more measures apply to the sample than would be expected in a housing stock sample containing a more typical distribution of properties rated A-G. This is unsurprising given the nature of the housing sample.

Notable is:

- a high percentage of solid wall properties (slightly higher in the G rated sample)
- a high percentage of homes with uninsulated lofts (slightly higher in the G rated sample)
- a high percentage of homes with on peak electric heating
- a high percentage of homes with LPG heating

The most prominent contrasts between Figure 7 (G rated properties) and Figure 8 are the differences between the proportion of E-G rated boilers (much higher in F rated

properties) and on-peak electric heating and LPG heating (much higher in G rated properties). The exceptionally high applicability of on-peak electric heating for the G rated properties demonstrates that the very worst performing properties in the sample are not only characterised by poor energy efficiency, but also by high cost fuels.

The characteristics of the F and G rated properties highlighted above tend to reinforce our experience that sub-E properties tend to be low rated either:

- as a result of a number of inefficient characteristics applying to the same property; or
- as a result of a very expensive heating fuel such as on-peak electricity or LPG.

5 Installation Scenarios

In this section we present the results of applying measures in order of cost effect (most cost effective first) to estimate the level of investment required to achieve a minimum SAP target of 39 (SAP band E). Note that this order is usually different to the order in which recommendations are provided on an Energy Performance Certificate. The full compatible measure set is listed in Appendix B: Energy-saving initiatives.

5.1 ACHIEVING MINIMUM SAP E

In this section we estimate the level of investment required to achieve a minimum SAP target of 39 (SAP band E).

By applying the set of ordered initiatives with the intention of reaching the target E:

all properties were able to achieve a SAP score of 39 or above (SAP band E), at an average cost of **£1,421 per property**

The average fuel bill saving (as calculated by RdSAP 2009) resulting from these measures is **£409** per home. This is a reflection of the extensive opportunities for measures with short financial paybacks in the inefficient housing in our sample, and represents an excellent average payback period of around 3-4 years. The average CO_2 saving is 1.9 tCO_2 per home (about 25% saving).

The measures result in an average SAP of 47.8 across the whole stock, an improvement of 18.4 SAP points from our estimate for the baseline of the sample (i.e. previous to any measures being installed) of 29.4 points. Figure 9 below shows the effect on the estimated SAP profile of the stock.

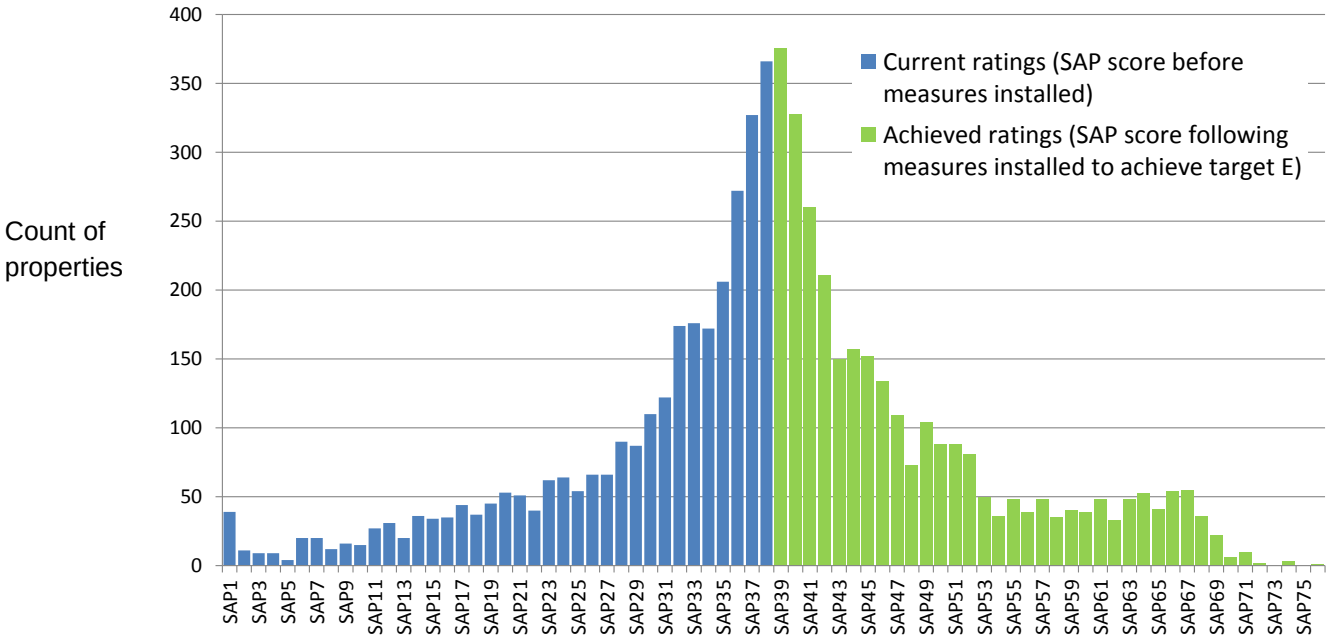


Figure 9: estimated SAP distributions in the sampled housing stock currently (blue) and following installation of 'Minimum E' measures (blue)

The cost of reaching the target varies across the sample, with the majority of properties achieving 'minimum E' at less than £1,000. As expected, properties with a lower baseline SAP score (e.g. G rated properties G (<21 SAP points)) cost more on average to achieve the minimum SAP target of E than those already relatively close to the minimum. The sampled properties are broken down in Figure 10 below by their baseline SAP band and the cost of achieving a SAP score of 39 or above.

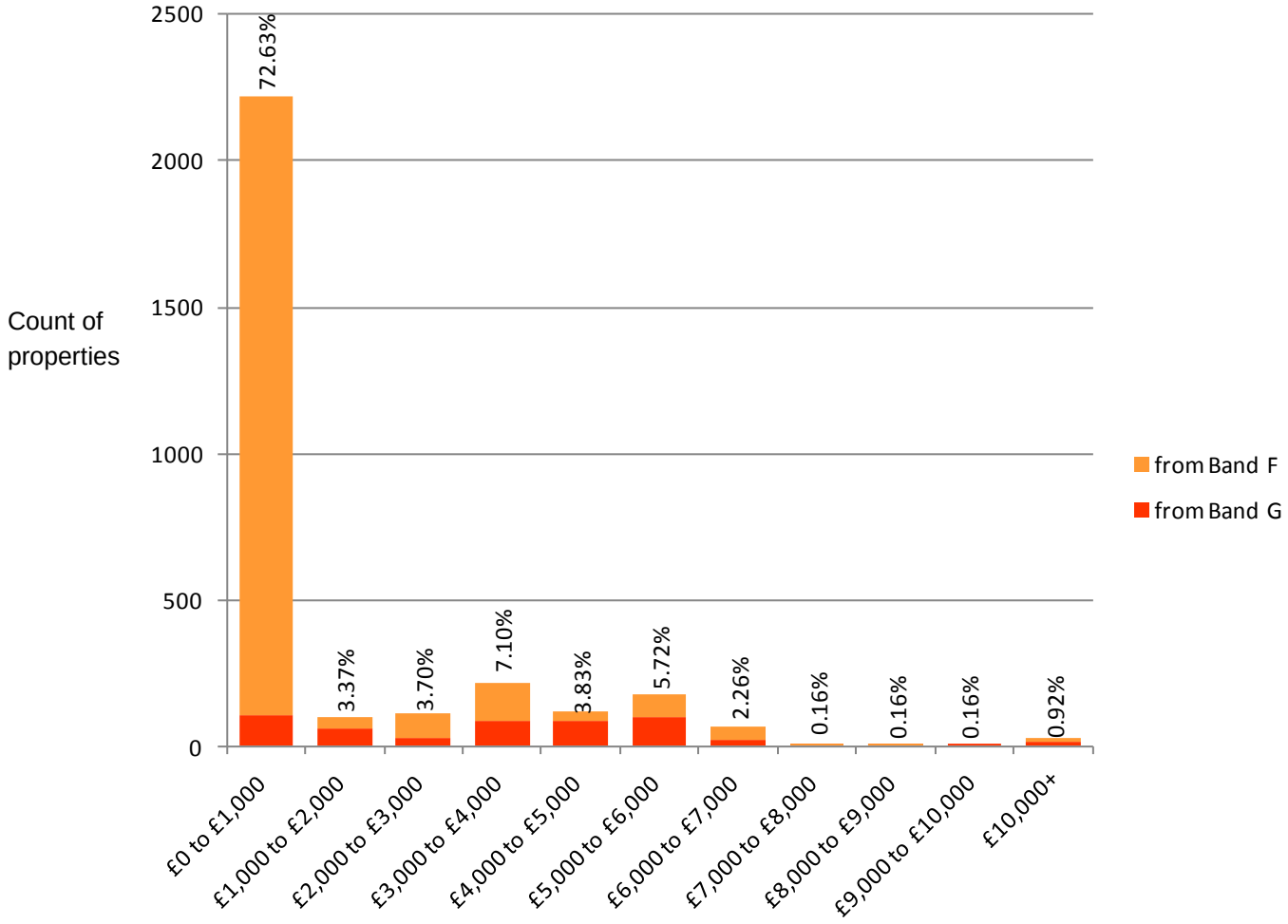


Figure 10: Count of properties in sample by cost band to achieve minimum SAP E with no restriction on measures, broken down by pre improvement SAP band

Please note that our computer model does not have the full flexibility of a human analyst so we expect that some of the properties modelled as meeting the targets might possibly reach the targets more cost effectively if creatively analysed individually by a suitably experienced analyst (see for example case study 2, section 6.2).

Nevertheless, the above illustrates that even unusual dwellings can achieve a SAP target of E relatively easily, and at a relatively low cost without resorting to 'special measures' (e.g. super insulation, insulation to alternate areas of wall, etc.). The full data, including a breakdown of the cost bands above £10,000, is available in the supplementary spreadsheet.

The full list of measures applied to the sampled properties in order to achieve a minimum SAP of E is provided in Appendix E.

5.2 ACHIEVING MINIMUM SAP 'E' – 'PLANNING FRIENDLY' SCENARIO

In this section we present the results of applying 'planning friendly' measures in order of cost effect (most cost effective first) to estimate the level of investment required to achieve a minimum SAP target of 39 (SAP band E).

The aim of this analysis is to demonstrate the extent to which the target can be achieved without applying measures that affect the external appearance of the dwelling. Measures excluded include solid wall insulation (SWI), double glazing, solar panels, and other measures that materially affect the appearance of "traditional" (pre-1919) properties. The full list of excluded measures is provided in Appendix C.

By applying the subset of ordered initiatives with the intention of reaching the target E:
all properties were able to achieve a SAP score of 39 or above (SAP band E), at an average cost of **£1,345 per property**

The average fuel bill saving (as calculated by RdSAP 2009) resulting from these measures is **£408** per home, very similar to the saving using the unrestricted measure set. This is a reflection of the fact that many of the measures excluded from the 'planning friendly' measure set do not have short enough paybacks to have been selected in the previous section (as illustrated in the case studies in section 6). The average CO_2 saving is 1.9 tCO_2 per home (about 25% saving).

This average cost is slightly lower than the result using the unrestricted measure set. This is because several of the measures judged not to be 'planning friendly' (notably solid wall insulation and solar photovoltaic panels) tend to result in particularly large savings. When measures are applied in order of cost effect these measures can result in considerable 'overshoot' of the SAP 39 target, at considerable additional cost in a small number of cases.

The measures result in an average SAP of **47.8** across the whole stock, an improvement of 18.4 SAP points from our estimate for the baseline of the sample (i.e. previous to any measures being installed) of 29.4 points. Figure 11 overleaf shows the effect on the estimated SAP profile of the stock.

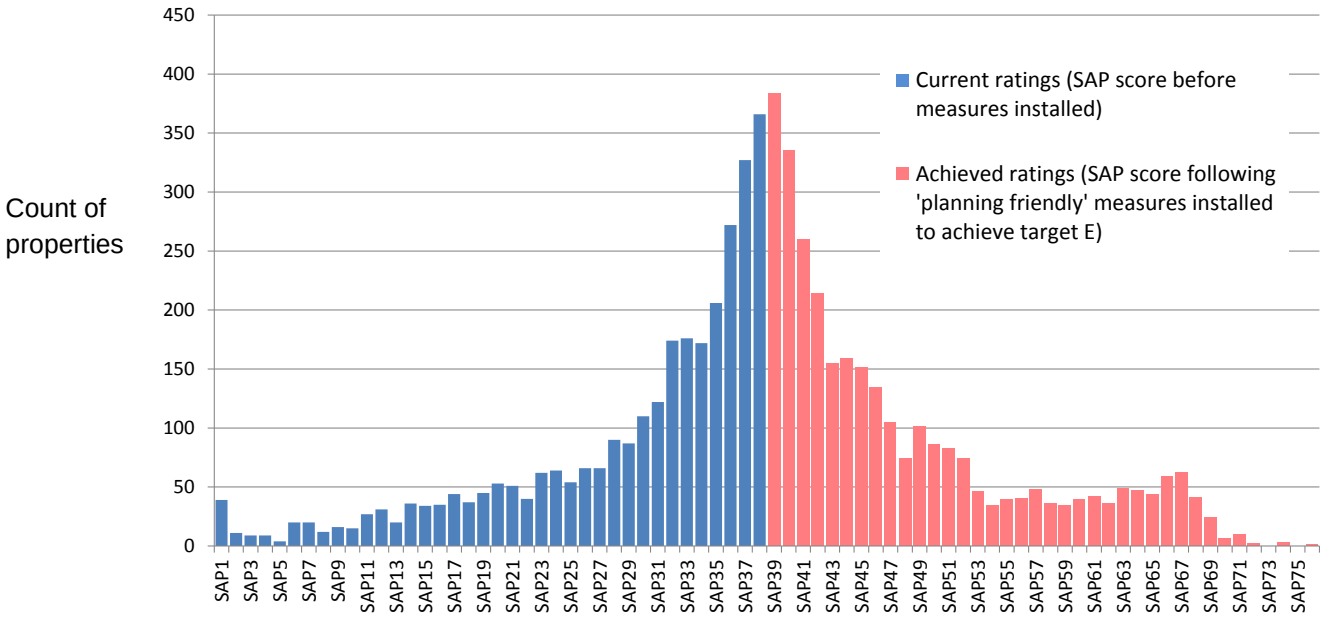


Figure 11: estimated SAP distributions in the sampled housing stock currently (blue) and following installation of selected 'Minimum E' measures (pink)

As with the full set of initiatives, the sampled properties have been broken down by their baseline SAP band and the cost of achieving a SAP score of 39 or above in Figure 12 overleaf.

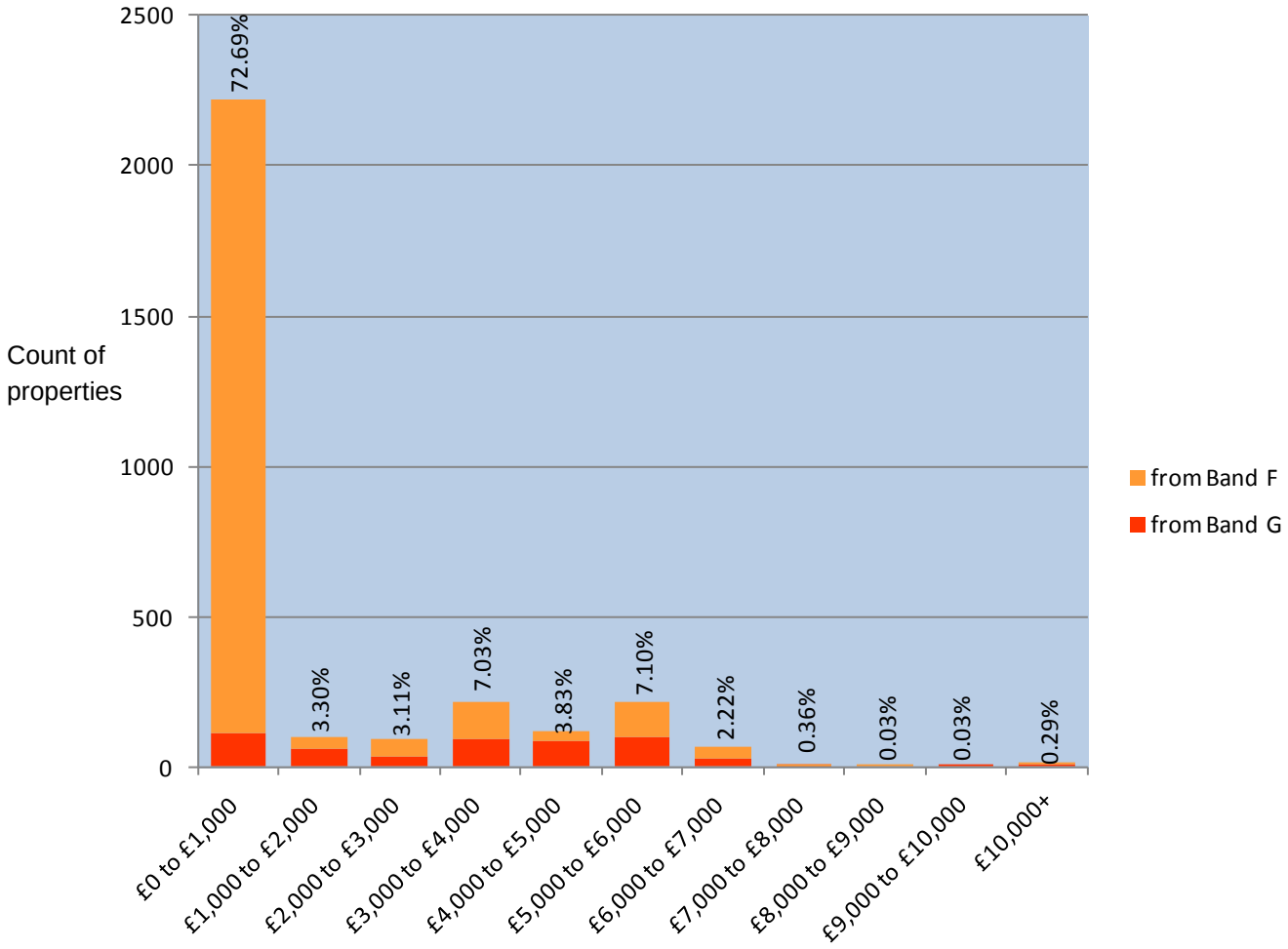


Figure 12: Count of properties in sample by cost band to achieve minimum SAP E using only 'planning friendly' initiatives, broken down by pre improvement SAP band

The above illustrates that even unusual dwellings can achieve a SAP target of E relatively easily, and at a relatively low cost without resorting to 'special measures' (e.g. super insulation, insulation to alternate areas of wall, etc.). The full data, including a breakdown of the cost bands above £10,000, is available in the supplementary spreadsheet.

The full list of measures applied to the sampled properties in order to achieve a minimum SAP of E is shown in shown in Appendix E.

6 Case studies

In this section we have provided detailed case studies for five heritage property types from within the sample. As the sample has been anonymised photographs are not provided, and listing / conservation area status is not available.

The case studies are all of pre 1900 homes, and have been selected to be broadly representative of the sample as described in section 3.2. We have therefore selected:

- a mix of G-rated and F rated properties
- three homes with solid brick walls, one with stone walls, one with timber frame walls
- one gas heated property, two electrically heated properties (one on-peak, one using dual tariff), one oil-heated property and one coal heated property
- one detached house

Where the target EPC Band E has been reached easily, we have included analysis to show how these properties could be bought up to D, for illustrative purposes only.

6.1 CASE STUDY 1: GRANITE HOUSE WITH STORAGE HEATERS

Property Overview

This granite end terraced cottage is in the rural South West, and has a pitched roof with 100mm existing insulation. It is heated by standard 'slimline' storage heaters with manual controls, and hot water is from a jacket insulated hot water cylinder with a single immersion heater only. The house is single glazed throughout with no draughtproofing, and although there is no open fire currently in commission there is an open chimney in the sitting room. The house has a SAP score of 33.92 (an EPC band F).

All measures applied to reach EPC band target

Measure Type	Measure Name	SAP	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
OPENING DRAUGHTS	Draughtproof all doors and windows	**35.52**	**F**	£1,325 **(£41)**	£50	£50	10.21 **(0.37)**
DRAUGHTS	Fit baffles to block open chimneys when not in use	**37.05**	**F**	£1,287 **(£79)**	£50	£100	9.87 **(0.71)**
HOT WATER	Single to dual immersion	**45.23**	**E**	£1,102 **(£265)**	£750	£850	9.34 **(1.24)**

Band E targets reached

'Planning Friendly' measures applied to reach EPC band target

Measure Type	Measure Name	SAP	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
OPENING DRAUGHTS	Draughtproof all doors and windows	**35.52**	**F**	£1,326 **(£41)**	£50	£50	10.21 **(0.37)**
DRAUGHTS	Fit baffles to block open chimneys when not in use	**37.05**	**F**	£1,288 **(£79)**	£50	£100	9.87 **(0.71)**
HOT WATER	Single to dual immersion	**45.23**	**E**	£1,102 **(£265)**	£750	£850	9.34 **(1.24)**

Band E targets reached

6.2 CASE STUDY 2: DETACHED SOLID BRICK HOUSE HEATED BY ON-PEAK HEATERS

Property Overview

This Victorian detached house is in a small village near a large town in Hampshire, and the village is on the gas network. It has solid brick walls, and modern electric (on-peak) panel heaters throughout with modern controls. The pitched roof has a loft with no insulation, and many of the original single glazed windows have been replaced by double glazed units, although the remaining single glazed windows are not draughtproofed. The house has a SAP score of 20.09 (a high EPC band G).

All measures applied to reach EPC band target

Measure Type	Measure Name	SAP	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
ROOF	Insulate loft from 0mm to 300mm	**29.56**	**F**	£1,224 **(£242)**	£350	£350	7.08 **(1.39)**
OPENING DRAUGHTS	Draughtproof all doors and windows	**30.73**	**F**	£1,197 **(£269)**	£80	£430	6.92 **(1.55)**
HEATING SYSTEM	Replace electric heaters with A rated combi system, Gas near property	**60.38**	**D**	£659 **(£808)**	£5,500	£5,930	3.36 **(5.11)**

Band E target and Band D reached simultaneously*

'Planning Friendly' measures applied to reach EPC band target

Measure Type	Measure Name	SAP (2dp)	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
ROOF	Insulate loft from 0mm to 300mm	**29.56**	**F**	£1,224 **(£242)**	£350	£350	7.08 **(1.39)**
OPENING DRAUGHTS	Draughtproof all doors and windows	**30.73**	**F**	£1,197 **(£269)**	£80	£430	6.92 **(1.55)**
HEATING SYSTEM	Replace electric heaters with A rated combi system, Gas near property	**60.38**	**D**	£659 **(£808)**	£5,500	£5,930	3.36 **(5.11)**

Band E target and Band D reached simultaneously*

*Note that the progressively applied measures in this case study reach Band D without first reaching the intermediate band of E. This illustrates the way in which our computer model does not have the full flexibility of a human analyst, with measures applied in strict order of cost-effect resulting in occasional 'overshoot' of targets.

6.3 CASE STUDY 3: SOLID BRICK BUILT SEMI DETACHED HOUSE HEATED BY GAS ROOM HEATERS

Property Overview

This early 19th century semi-detached house is in the outskirts of a town in the Welsh borders and is of solid brick construction, with a pitched roof with 250mm loft insulation. It is heated with old fashioned 'fuel effect' gas room heaters with no controls. It has several low energy light bulbs but a number of incandescent bulbs remain. The house has a SAP score of 3.69 (a low EPC band G).

All measures applied to reach EPC band target

Measure Type	Measure Name	SAP (2dp)	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
HEATING SYSTEM	Upgrade gas room heaters to new central heating with combi	**64.16**	**D**	£664 **(£1,568)**	£3,300	£3,300	3.37 **(9.29)**
		Band E target and Band D reached simultaneously					

'Planning Friendly' measures applied to reach EPC band target

Measure Type	Measure Name	SAP (2dp)	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
HEATING SYSTEM	Upgrade gas room heaters to new central heating with combi	**64.16**	**D**	£664 **(£1,568)**	£3,300	£3,300	3.37 **(9.29)**
		Band E target and Band D reached simultaneously					

6.4 CASE STUDY 4: TIMBER FRAME DETACHED HOUSE HEATED BY EFFICIENT OIL BOILER

Property Overview

This early Victorian semi-detached house in Surrey is of timber frame construction throughout. It has a pitched roof, with an uninsulated loft. There is a modern condensing combi boiler which has not been identified by model in the EPC survey, and there is also a log stove in the sitting room. The kitchen and upstairs bedroom have chimneys blocked with newspaper (deemed 'open' according to RdSAP convention). The property is single glazed, although some of the windows and both doors are draughtproofed. Many incandescent light bulbs remain. The house has a SAP score of 36.45 (EPC band F).

All measures applied to reach EPC band target

Measure Type	Measure Name	SAP (2dp)	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
HEATING DATA	Add actual PCDF boiler reference to RdSAP data using an average boiler for the known category	**41.45**	**E**	£1,088 **(£109)**	£0	£0	7.69 **(0.73)**
		Band E target reached					
DRAUGHTS	Fit baffles to block open chimneys when not in use	**42.90**	**E**	£1,058 **(£138)**	£50	£50	7.47 **(0.95)**
OPENING DRAUGHTS	Draughtproof all doors and windows	**44.12**	**E**	£1,034 **(£163)**	£50	£100	7.29 **(1.13)**
ROOF	Insulate loft from 0mm to 300mm	**52.92**	**E**	£872 **(£325)**	£350	£450	6.09 **(2.33)**
SECONDARY HEATING	Remove secondary solid fuel heaters	**56.55**	**D**	£805 **(£392)**	£250	£700	5.20 **(3.22)**
		Band D reached					

'Planning Friendly' measures applied to reach EPC band target

Measure Type	Measure Name	SAP (2dp)	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
HEATING DATA	Add actual PCDF boiler reference to RdSAP data using an average boiler for the known category	**41.45**	**E**	£1,088 **(£109)**	£0	£0	7.69 **(0.73)**
		Band E target reached					
DRAUGHTS	Block open chimneys	**42.90**	**E**	£1,058 **(£138)**	£50	£50	7.47 **(0.95)**
OPENING DRAUGHTS	Draughtproof all doors and windows	**44.12**	**E**	£1,034 **(£163)**	£50	£100	7.29 **(1.13)**
ROOF	Insulate loft from 0mm to 300mm	**52.92**	**E**	£872 **(£325)**	£350	£450	6.09 **(2.33)**
SECONDARY HEATING	Remove secondary solid fuel heaters	**56.55**	**D**	£805 **(£392)**	£250	£700	5.20 **(3.22)**
		Band D reached					

6.5 CASE STUDY 5: BRICK SEMI DETACHED HEATED BY COAL FIRES

Property Overview

This semi-detached house in Cambridgeshire has walls is built of solid brick, a pitched roof with 75mm insulation, and is heated by coal open fires. Portable electric heaters provide secondary heating and hot water is from a foam insulated tank heated by a dual rate immersion heater. Windows are single glazed throughout. The house has a SAP score of 11.72 (EPC band G).

All measures applied to reach EPC band target

Measure Type	Measure Name	SAP (2dp)	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
DRAUGHTS	Fit baffles to block open chimneys when not in use	13.66	G	£1,846 **(£70)**	£50	£50	17.17 **(0.71)**
OPENING DRAUGHTS	Draughtproof all doors and windows	15.44	G	£1,784 **(£131)**	£50	£100	16.55 **(1.33)**
SECONDARY HEATING	Remove secondary portable electric heaters	17.31	G	£1,722 **(£194)**	£200	£300	17.32 **(0.56)**
WWHRS	Retrofit WWHRS in suitable shower or shower and bath rooms	23.85	F	£1,521 **(£395)**	£650	£950	16.23 **(1.65)**
HEATING SYSTEM	Upgrade solid fuel room heaters to new oil central heating with combi	63.37	D	£678 **(£1,237)**	£5,000	£5,950	4.41 **(13.47)**

Band E target and Band D reached simultaneously*

'Planning Friendly' measures applied to reach EPC band target

Measure Type	Measure Name	SAP (2dp)	EPC band	Fuel Bill estimate (saving)	Measure Cost	Cumulative Cost	tCO_2 estimate (saving)
DRAUGHTS	Block open chimneys	13.66	G	£1,846 **(£70)**	£50	£50	17.17 **(0.71)**
OPENING DRAUGHTS	Draughtproof all doors and windows	15.44	G	£1,784 **(£131)**	£50	£100	16.55 **(1.33)**
SECONDARY HEATING	Remove secondary portable electric heaters	17.31	G	£1,722 **(£194)**	£200	£300	17.32 **(0.56)**
WWHRS	Retrofit WWHRS in suitable shower or shower and bath rooms	23.85	F	£1,521 **(£395)**	£650	£950	16.23 **(1.65)**
HEATING SYSTEM	Upgrade solid fuel room heaters to new oil central heating with combi	63.37	D	£678 **(£1,237)**	£5,000	£5,950	4.41 **(13.47)**

Band E target and Band D reached simultaneously*

*Note that the progressively applied measures in this case study reach band D without first reaching the intermediate band of E. This illustrates the way in which our computer model does not have the full flexibility of a human analyst, with measures applied in strict order of cost-effect resulting in occasional 'overshoot' of targets.

7 Methodology

The work has consisted largely of:

- Data extraction, anonymisation and cleaning of past stock condition survey data for the properties in the sample
- Analysis and computer modelling of the housing sample based on the data available.

The accuracy of the findings of this report is based on the accuracy of various incomplete datasets that have been cloned and collated into a single dataset.

The base data used in our stock assessments are rarely fully complete but generally provide a good basis for cloning exercises with the majority of the essential data points covered. Data cleaning and cloning is carried out to construct the complete dataset, and where inconsistencies are present in the data some judgement has to be used in selecting which data should be used. We have tried to indicate where analysis results have been based on real data, and where they have been based on extrapolation and assumptions.

7.1 EXTRAPOLATION OF MISSING DWELLING CHARACTERISTICS

After the integration of all the data, the majority of the addresses sampled possessed a high level of primary data. In order to produce a workable dataset a cloning approach was taken as described below.

First, the basic built form and build date is used to define archetypes which are then used to clone out the available data to the necessary addresses. For the remaining empty data points a proportional distribution are used to fill in the required data points.

7.2 MODELLING

For the sampled dwellings we used our specialist *CROHM*[5] software and detailed analysis to:

- extract the energy/carbon saving measures possible for each dwelling
- calculate the base fuel cost[6], indicative SAP and estimated CO_2 for each dwelling
- calculate the energy use, indicative SAP improvement, carbon saving and cost of each carbon saving measure identified

[5] See Appendix A for more details

[6] Using standard tariffs as specified in SAP 2009

7.2.1 Domestic Carbon Modelling

Carbon saving initiatives are determined based on dwelling characteristics (e.g. if the model finds a dwelling with solid walls, the model is set to generate initiatives for various solid wall options such as solid wall insulation). These initiatives are used to adjust the model of the individual dwelling, and to calculate the energy, carbon and cost effect of each initiative on the particular dwelling. The costing basis used for this analysis is provided in Appendix D: Price framework used to estimate cost of .

The *CROHM* software was used to estimate the energy use, carbon footprint, and potential energy saving initiatives for every dwelling in the stock using an RdSAP based approach more fully described in Appendix A.

7.2.2 Indicative SAP ratings

In addition to the data above, we have calculated a SAP2009 rating for each dwelling and each initiative in order to provide an indication of the potential for a given initiative to improve the SAP rating of the properties sampled for WWF and UK-GBC. No properties had all of the necessary data to conduct the assessment to full RdSAP level, so all SAP scores should be regarded as both approximate and indicative only.

In addition it should be noted that our software uses the approved SAP 2009 / RdSAP9.91 methodology but cannot be accredited to provide EPC/SAP ratings as we do not manage an EPC scheme. While we believe that the SAP calculations underlying the information provided in this report are correct, and that the conclusions in this report are appropriate for strategic planning, our SAP ratings cannot be used for purposes where EPCs are required.

7.3 OVERVIEW AND EXPLANATION OF REPORT CONCEPTS / TERMINOLOGY

This section provides a brief introduction to some of the methods, concepts and terminology used in this report, and in the underlying analysis.

7.3.1 SAP

SAP stands for Standard Assessment Procedure. It is a method for assessing the energy performance of houses using a standard methodology specified by the UK government. The current version of SAP is SAP 2009, and it calculates a 'SAP rating' as well as an estimate of energy bills and CO_2 emissions associated with the estimated energy use.

The SAP calculations are based on building dimensions, construction (and therefore energy performance) of building elements such as walls and windows, details of the heating and hot water systems and controls, and any installed renewable technologies including solar PV panels. The number and percentage of low energy light fittings is noted, but the calculations do not take note of other electrical appliances and actual occupancy and heating usage (temperatures, heating hours, hot water usage, etc.), or actual fuel tariffs (standard typical energy prices are used).

A SAP survey is a relatively time consuming process (perhaps 2 hours work), and is usually only required for new build housing etc.

7.3.2 RDSAP

RDSAP is the method used to produce Energy Performance Certificates (EPCs). RD stands for Reduced Data, and the method is designed to allow surveys to be completed more quickly and therefore more cheaply than a full SAP survey at some cost of accuracy. The reduced data survey is extrapolated up to full SAP level data using a standard set of rules before SAP calculations can be conducted. The current version of RDSAP is 9.91 and is used as the basis of the Green Deal survey.

7.3.3 Link between SAP score and fuel bills

The SAP score is a number, nominally between 1 and 100, which is calculated using a slightly abstruse algorithm which takes as inputs the floor area and estimated fuel bills. The SAP score is divided into rating bands which are used in EPCs. A higher SAP score is better than a lower SAP score, and a typical Registered Provider currently has a SAP score around 70. [Note: it is theoretically possible to have a SAP score above 100 if energy bills are negative (e.g. if exported energy fees exceed bills for energy used.]

7.3.4 General Approach

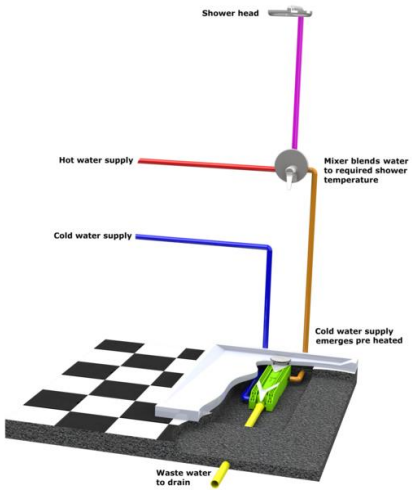
Throughout our analysis we have used RDSAP as the basis for our calculations of SAP score, CO_2 emissions and fuel bills.

7.3.5 Introduction to some newer technologies mentioned in the report

These technologies are fairly new in the market and have low market penetration at present.

Waste Water Heat Recovery Systems (WWHRS)

These systems recover heat from warm water that flows out of a shower tray outlet (or bath outlet) and use this to warm up the cold water input into the mixer shower, into the boiler, or into the hot water cylinder. They are generally well suited to mixer showers, as depending on their installation they may sometimes be unable to make use of warm water from a bath. As they require a good or moderate flow of water in order to deliver net fuel bill savings they are generally not suitable for electric showers or showers with a low flow showerhead fitted. WWHRS does require a certain amount of space, but is sometimes incorporated within a shower tray and can generally be fitted on ground or upper floors.



Schematic of a simple WWHRS installation

WWHRS can be modelled in RdSAP and usually results in SAP savings. Although a low flow showerhead may result in larger savings than FGHRS, low flow showerheads cannot be modelled in SAP.

Flue Gas Heat Recovery Systems (FGHRS)

Flue Gas Heat Recovery systems extract and recycle heat from boiler flue gases. They are compatible with most modern boilers and are fitted above the boiler, but are incompatible with most older boilers. They generate appreciable savings.

While they can be retrofitted to existing boilers (if FGHRS compatible) this generally requires the boiler to be re-sited to accommodate the FGHRS unit above the boiler so may be impractical. For similar reasons they may not be suitable for replacement boilers in situation where space is tight (see image to right)**.**

FGHRS fitted above a normal boiler

Appendix A: *CROHM* stock assessment method

The *CROHM* (Carbon Reductions Options for Housing Managers) model uses data about building characteristics and resident behaviour to derive an accurate estimate of the annual energy and carbon usage of dwellings. It then applies an initiative algorithm to derive the cost, savings and payback of a very wide variety of possible carbon saving measures that apply to the individual dwelling and to the preferences and requirements of the client. Costs can be based on dwelling characteristics (e.g. wall insulation can be based on the sum of a flat rate and a per m^2 wall area) and so are realistically applied to each building in turn. The cost rates are derived from our experience of carrying out the work, but can be revised for any situation, for instance where a framework contract is in place for installation of measures.

In addition, the model and accompanying analysis allows custom initiatives to be applied: this functionality allows any realistic change to a building to be model, and affords a great deal of flexibility in allowing for future scenarios such as extensions or emerging innovative measures. The calculations used by the model are based on SAP 2009.

In stock assessment, where details are unknown (e.g. loft insulation, heating pattern, heating temperature) assumptions are made based on expected proportions of houses with a particular characteristic. Where possible, this is done based on known statistics from the stock. Where this is not possible assumptions can be made using other data sources, or based on sensible estimates. The assumptions made for this analysis are stated in the report.

CROHM used for stock assessment produces estimated current fuel use for every dwelling considered in an area, in parallel with estimated fuel use and typical installation cost for every energy/CO_2 saving measure that can be applied to each dwelling. These model outputs can be used to derive cost savings, carbon savings, paybacks, and so on. It should be understood that where the model outputs are based on assumptions, they should be used primarily as a strategic tool as outputs for individual dwellings may have limited applicability. However, CROHM is also designed with the key aim of distinguishing conclusions drawn from real and cloned data.

Appendix B: Energy-saving initiatives

A range of energy-saving measures have been considered and modelled for the sampled F and G rated housing stock. The range of measures considered are summarised in this section, and are broken down and presented in terms of their cost-effectiveness in reducing carbon, improving SAP ratings, and reducing tenants' fuel bills.

Measures Considered

Following review of sampled housing stock the following list of measures were investigated:

Floors

- Insulate above solid floors
- Insulate below suspended floors
- Externally insulate exposed floors

Draughts

- Fit baffles to block open chimneys when not in use
- Draughtproofing to windows and doors

Glazing

- Upgrade old[7] double glazing to new double glazing and triple glazing
- Upgrade new double glazing to triple glazing

Lighting

- Upgrade remaining inefficient lighting[8]

Heating System

- Replace old[9] existing regular boilers with combi
- Replace old[5] existing combi boilers with combi
- Replace old[5] regular existing boilers with new efficient regular boilers
- Replace storage heaters with new A rated combi gas central heating (where gas is in the building, or the postcode)
- Replace storage heaters with new A rated combi gas central heating (where no gas is in the postcode)
- Upgrade older storage heaters to fan storage heaters
- Upgrade older storage heaters to electric combined primary storage unit (CPSU)
- Upgrade boilers to Air Source Heat Pump (ASHP)

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[7] pre-2002

[8] This measure may include installation of low energy light bulbs in conventional fittings where this is possible

[9] B rated and lower, itemised by rating band

- Upgrade boilers (houses only) to Ground Source Heat Pump (GSHP)
- Remove inefficient secondary heating
- Change secondary heating fuel to cheaper option
- Upgrade gas fires to new A rated combi gas central heating
- Add PCDF[10] reference for boiler instead of generic SAP table entry
- Remove inefficient or on peak electric secondary heating
- Replace warm-air heating system with A rated combi system
- Replace electric heaters with fan storage heaters
- Upgrade solid fuel room heaters to new oil central heating with combi
- Upgrade oil room heaters to new oil central heating with combi
- Decommission electric ceiling heaters, replace with fan storage heaters
- Decommission electric ceiling heaters, replace with gas combi system
- Above boiler upgrade options with Flue Gas Heat Recovery (FGHRS)

Hot Water

- Replace cylinders of various assumed specifications with new cylinder with 80mm foam insulation
- Add jacket to uninsulated cylinders
- Add hot water tank thermostat
- Waste Water Heat Recovery (WWHRS)

Controls

- Upgrade central heating controls to full (programmer, Thermostatic Radiator Valves, room thermostat)
- Upgrade central heating controls to full zone controls
- Upgrade manual storage heater controls to automatic
- Upgrade communal controls to full with tariff based on usage

Roof

- Insulate loft from current to 300mm

Solar

- Install solar hot water
- Install PV panels

Walls

- Install external wall insulation to solid walls (various age bands, brick and stone)
- Install internal wall insulation to solid walls (various age bands, brick and stone)
- Insulate pre-1977 cavity walls
- Insulate 1977-81 cavity walls
- Insulate pre 1975 system built walls internally / externally

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[10] Product Characteristics Data File. This is a national database containing performance data for a range of heating and other appliances to be used in SAP modelling.

Appendix C: Initiatives ruled out of 'planning friendly' scenario

Glazing

- Replace single glazing with new double glazing
- Check or replace double glazing of unknown age with new double glazing
- Replace any remaining single glazing in part double glazed property
- Replace secondary glazing with new double glazing

Flat roof

- Add 100mm or equivalent internally to existing pre 1966 flat roof
- Add 100mm or equivalent internally to existing 1966-1975 flat roof
- Add 100mm or equivalent internally to existing 1976-1982 flat roof

Panels

- Install solar hot water panels where existing system includes hot water cylinder
- Add panels on South facing roof
- Add panels on SE/SW facing roof
- Add panels on E/W facing roof
- Add panels on South facing roof
- Add panels on SW/SE facing roof
- Add panels on E/W facing roof

Walls

- Insulate pre 1976 solid walls externally
- Insulate 1976-1982 solid walls externally
- Insulate 1983-1990 solid walls externally
- Apply external insulation to pre 1976 hard to treat cavity walls
- Apply external insulation to 1976-1982 hard to treat cavity walls
- Insulate 1900-1966 stone walls externally
- Insulate 1967-1983 stone main walls externally
- Insulate pre 1976 unknown system built walls externally
- Insulate 1900-1966 timber frame walls internally
- Add external insulation to filled pre 1976 cavity walls
- Add external insulation to filled 1976-1982 cavity walls
- Fill and add external insulation to empty 1976-1982 cavity walls
- Fill and add external insulation to empty pre 1976 cavity walls
- Insulate pre 1976 unknown system built walls externally
- Upgrade of system built properties:
    - Insulate Airey system house externally (assuming no additional structural work needed)
    - Insulate Hawthorne Leslie system house externally (assuming no additional structural work needed)
    - Insulate Trusteel3M system dwelling externally (assuming no additional structural work needed)

- Insulate Wimpey no fines system dwelling externally
- Insulate as-built Cornish system house externally (assuming no additional structural work needed)
- Insulate Crosswall type 2 dwelling fill uninsulated cavities if needed and add external cladding as needed to address thermal bridging
- Externally insulate LPS Sellick Nicholls main and infill wall sections
- Externally insulate Trusteel Mk2 steel framed cavity walls
- Insulate Wates Walsall Halifax system dwelling externally
- Externally insulate BISF cavity walls
- Externally insulate Orlit type 2 walls if can be stabilised
- Externally insulate Spooner walls using appropriate system
- Externally insulate Wates PRC and cavity walls
- Externally insulate walls of Boot system homes

Appendix D: Price framework used to estimate cost of measures

Initiative	Cost per Unit	Cost Unit
4m2 flat plate Solar Hot Water	(per dwelling)	£3,500
Add communal controls to allow charging based on usage	(per dwelling)	£1,000
Add cylinder jacket	(per dwelling)	£40
Add efficient lighting	(per lamp)	£20
Add hot water tank thermostat	(per dwelling)	£300
Add new central heating with oil combi	(per dwelling)	£5,000
Add new double glazing from double	(per m2 window area)	£250
Add new double glazing from single	(per m2 window area)	£250
Add new gas wet central heating to replace gas warm air	(per dwelling)	£3,000
Add new triple glazing from double	(per m2 window area)	£370
Add new triple glazing from single	(per m2 window area)	£370
Fit baffles to block open chimneys when not in use	(per open fireplace)	£50
Cavity Wall Insulation	(per dwelling)	£300
Change to cheaper secondary heating fuel	(per dwelling)	£0
Draughtproofing (windows/doors)	(per dwelling) + (x fraction without draughtproofing)	£50 + ((fraction without draughtproofing)*£150)
External Solid Wall Insulation to main walls	(per m2 wall area)	£90
Full controls package Thermostatic Radiator Valves, Thermostat Programmer	(per dwelling)	£500
Full zone controls	(per dwelling)	£600
Gas connection distance unknown Replace Storage Heaters with A rated combi system	(per dwelling)	£5,000
Gas in property Replace Storage Heaters with A rated combi system	(per dwelling)	£3,300
Gas near property Replace Storage Heaters with A rated combi system	(per dwelling)	£5,500
Install ASHP	(per dwelling)	£7,500
Install Electric CPSU	(per dwelling)	£4,000
Install fan storage heaters and decommission old system	(per dwelling)	£2,500
Install GSHP	(per dwelling)	£11,000
Install insulated doors	(per door)	£900

Initiative	Cost per Unit	Cost Unit
Insulate under timber floors without cellar	(per m2 floor area) + (per dwelling)	£25/m2 + £400
Internal flat roof insulation	(per m2 roof area)	£50
Internal Solid Wall insulation to main walls	(per m2 wall area)	£55
Loft Insulation From 0mm	(per dwelling)	£350
Loft Insulation Top up	(per dwelling)	£300
Part controls pack room stat or programmer and Thermostatic Radiator Valves	(per dwelling)	£280
PV panels per kWp capacity	(per kWp) + (per dwelling)	£600 with an additional £1,350 per installed kWp.
Remove secondary electric portable heaters	(per dwelling)	£200
Remove secondary gas heaters	(per dwelling)	£250
Remove secondary non-portable electric heaters	(per dwelling)	£200
Remove secondary solid fuel heaters	(per dwelling)	£250
Replace hot water cylinder	(per dwelling)	£750
Solid floor insulation	(per m2 floor area) + (per dwelling)	£30/m2 + £400
Upgrade combi boiler	(per dwelling)	£1,500
Upgrade communal controls	(per dwelling)	£1,000
Upgrade community heating, & upgrade controls	(per dwelling)	£2,500
Upgrade regular boiler	(per dwelling)	£2,400
Upgrade boiler with FGHRS	(per dwelling)	£2,500
Upgrade regular boiler to combi with FGHRS	(per dwelling)	£2,800
Upgrade manual storage heating controls to automatic charge control	(per dwelling)	£400
Waste Water Heat Recovery	(per dwelling) + (per wet room installed)	£300 + £350 / wet room installed

Appendix E: Achieving minimum SAP levels: detail

Detail of measures applied to reach minimum SAP E

As described in section 5.1 (p 17), we aimed to reach a target minimum SAP E (39 SAP points) by iteratively applying initiatives in order of cost effect to each individual property until the target was reached. The actual measures applied to reach this target at minimum cost are detailed below.

Initiative	Number of measures	Estimated average cost per SAP point per home	Total investment
CONTROLS - Upgrade communal controls from programmer and TRV controlled flat rate to fully controlled and charging based on usage	1	£1,000	£1,000
CONTROLS - Upgrade communal controls from programmer only controlled flat rate to fully controlled and charging based on usage	1	£1,000	£1,000
CONTROLS - Upgrade communal controls from uncontrolled flat rate to charging based on usage	1	£1,000	£1,000
CONTROLS - Upgrade manual storage heater controls to automatic charge control	32	£400	£12,800
CONTROLS - Upgrade to full zone controls (add room thermostat) from programmer and multiple room stats	3	£600	£1,800
CONTROLS - Upgrade to full zone controls (add room thermostat) from programmer TRVs and bypass	26	£600	£15,600
CONTROLS - Upgrade to full zone controls (TRVs, programmer room thermostat) from no controls	12	£600	£7,200
CONTROLS - Upgrade to full zone controls (TRVs, programmer) from single programmer and room thermostat only	24	£600	£14,400
CONTROLS - Upgrade to full zone controls (TRVs, room thermostat) from single programmer only	70	£600	£42,000
CONTROLS - Upgrade to full zone controls from full normal controls set	55	£600	£33,000
DRAUGHTS - Fit baffles to block open chimneys when not in use	331	£77	£25,350
GLAZING - Replace any remaining single glazing in part double glazed property	6	£610	£3,662
GLAZING - Replace single glazing with new double glazing	1	£2,532	£2,532
HEATING DATA - Add actual PCDF boiler reference to RdSAP data using an average boiler for the known category	883	£0	£0
HEATING FUEL - Replace bottled LPG with bulk LPG	75	£500	£37,500
HEATING SYSTEM - Decommission Electric ceiling heaters, replace with fan storage heaters	8	£2,500	£20,000
HEATING SYSTEM - Decommission Electric ceiling heaters, replace with gas combi (gas near or in property)	21	£5,500	£115,500
HEATING SYSTEM - Decommission Electricaire, replace with fan storage heaters	1	£2,500	£2,500
HEATING SYSTEM - Decommission Electricaire, replace with gas combi	7	£5,500	£38,500
HEATING SYSTEM - Replace electric boiler with A rated combi system, Gas connection distance unknown	2	£5,000	£10,000
HEATING SYSTEM - Replace electric boiler with A rated combi system, Gas in property	2	£3,300	£6,600

Initiative	Number of measures	Estimated average cost per SAP point per home	Total investment
HEATING SYSTEM - Replace electric boiler with A rated combi system, Gas near property	3	£5,500	£16,500
HEATING SYSTEM - Replace electric boiler with fan storage heaters	44	£2,500	£110,000
HEATING SYSTEM - Replace electric heaters with A rated combi system, Gas in property	184	£3,300	£607,200
HEATING SYSTEM - Replace electric heaters with A rated combi system, Gas near property	141	£5,500	£775,500
HEATING SYSTEM - Replace electric heaters with fan storage heaters, Gas distance unknown	18	£2,500	£45,000
HEATING SYSTEM - Replace electric heaters with fan storage heaters, No gas near	2	£2,500	£5,000
HEATING SYSTEM - Replace Storage Heaters with A rated combi system, Gas in property	13	£3,300	£42,900
HEATING SYSTEM - Replace Storage Heaters with A rated combi system, Gas near property	21	£5,500	£115,500
HEATING SYSTEM - Upgrade C rated gas combi to A rated combi system with FGHRS	1	£2,500	£2,500
HEATING SYSTEM - Upgrade C rated LPG boiler to A rated LPG combi	1	£3,500	£3,500
HEATING SYSTEM - Upgrade community heating to Gas CHP, upgrade controls	1	£2,500	£2,500
HEATING SYSTEM - Upgrade E rated LPG boiler to A rated LPG combi	3	£3,500	£10,500
HEATING SYSTEM - Upgrade E rated oil boiler to A rated oil combi	1	£3,500	£3,500
HEATING SYSTEM - Upgrade electric underfloor storage heating in concrete slab to fan storage heaters	4	£2,500	£10,000
HEATING SYSTEM - Upgrade electric underfloor storage heating in screed to fan storage heaters	7	£2,500	£17,500
HEATING SYSTEM - Upgrade F equivalent solid fuel boiler to A rated oil combi	2	£3,500	£7,000
HEATING SYSTEM - Upgrade F rated gas combi to A rated combi system with FGHRS	1	£2,500	£2,500
HEATING SYSTEM - Upgrade F rated LPG boiler to A rated LPG combi	25	£3,500	£87,500
HEATING SYSTEM - Upgrade G rated gas combi to A rated combi system with FGHRS	2	£2,500	£5,000
HEATING SYSTEM - Upgrade G rated LPG boiler to A rated LPG combi	48	£3,500	£168,000
HEATING SYSTEM - Upgrade gas room heaters to new central heating with combi	12	£3,300	£39,600
HEATING SYSTEM - Upgrade LPG room heater to new LPG combi	6	£3,500	£21,000

Initiative	Number of measures	Estimated average cost per SAP point per home	Total investment
HEATING SYSTEM - Upgrade modern slimline storage heaters to fan storage heaters	19	£2,500	£47,500
HEATING SYSTEM - Upgrade oil room heaters to new oil central heating with combi	3	£5,000	£15,000
HEATING SYSTEM - Upgrade old storage heaters to ASHP	4	£7,500	£30,000
HEATING SYSTEM - Upgrade old storage heaters to fan storage heaters	6	£2,500	£15,000
HEATING SYSTEM - Upgrade regular E rated gas boiler to A rated combi system with FGHRS	1	£2,800	£2,800
HEATING SYSTEM - Upgrade regular G rated gas boiler to A rated combi system with FGHRS	8	£2,800	£22,400
HEATING SYSTEM - Upgrade solid fuel room heaters to new oil central heating with combi	27	£5,000	£135,000
HOT WATER - Check or upgrade inaccessible cylinder to 80mm jacket	146	£16	£2,336
HOT WATER - Retrofit WWHRS in suitable shower or shower and bath rooms	284	£652	£185,300
HOT WATER - Single to dual immersion	153	£750	£114,750
LIGHTING - Upgrade remaining inefficient lighting	114	£156	£17,732
OPENING DRAUGHTS - Draughtproof all doors and windows	666	£54	£35,639
ROOF - Add loft insulation to uninsulated thatched roof	2	£350	£700
ROOF - Check or add insulation to loft with unknown insulation	38	£301	£11,450
ROOF - Insulate loft from 0mm to 300mm	756	£350	£264,600
ROOF - Insulate loft from 100mm to 300mm	23	£300	£6,900
ROOF - Insulate loft from 12mm to 300mm	63	£300	£18,900
ROOF - Insulate loft from 150mm to 300mm	4	£300	£1,200
ROOF - Insulate loft from 25mm to 300mm	16	£300	£4,800
ROOF - Insulate loft from 50mm to 300mm	43	£300	£12,900
ROOF - Insulate loft from 75mm to 300mm	14	£300	£4,200
SECONDARY HEATING - Remove secondary gas heaters	35	£250	£8,750
SECONDARY HEATING - Remove secondary non-portable electric heaters	107	£200	£21,400
SECONDARY HEATING - Remove secondary portable electric heaters	53	£200	£10,600
SECONDARY HEATING - Remove secondary solid fuel heaters	41	£250	£10,250
SOLAR PV - Add panels on E/W facing roof	3	£6,675	£20,025
SOLAR PV - Add panels on SE/SW facing roof	1	£6,675	£6,675
SOLAR PV - Add panels on South facing roof	2	£1,950	£3,900
TARIFF SWITCH - Switch tariff from single to dual	524	£0	£0
WALLS - Cavity wall insulation to 1976-1982 cavity wall	7	£700	£4,900
WALLS - Cavity wall insulation to 1983-1995 cavity wall	1	£700	£700
WALLS - Cavity wall insulation to pre 1976 cavity wall	144	£700	£100,800
WALLS - Insulate 1900-1966 stone walls externally	13	£9,291	£120,789
WALLS - Insulate 1900-1966 timber frame walls internally	5	£5,507	£27,535
WALLS - Insulate Airey system house externally (assuming no additional structural work needed)	1	£12,008	£12,008
WALLS - Insulate pre 1976 solid walls externally	82	£6,148	£504,157
TOTAL			**£4,291,739**
AVERAGE INVESTMENT			**£1,421**

Figure 13: Measures applied over the sampled stock to achieve a minimum SAP score of 39

Detail of measures applied to reach minimum SAP E using only selected 'planning friendly' initiatives

As described in section 0 (p 19), we aimed to reach a target minimum SAP E (39 SAP points) by iteratively applying initiatives that do not significantly affect the external appearance of dwellings in order of cost effect to each individual property until the target was reached. The actual measures applied to reach this target at minimum cost are detailed below.

Initiative	Number of measures	Estimated average cost per SAP point per home	Total investment
CONTROLS - Upgrade communal controls from programmer and TRV controlled flat rate to fully controlled and charging based on usage	1	£1,000	£1,000
CONTROLS - Upgrade communal controls from programmer only controlled flat rate to fully controlled and charging based on usage	1	£1,000	£1,000
CONTROLS - Upgrade communal controls from uncontrolled flat rate to charging based on usage	1	£1,000	£1,000
CONTROLS - Upgrade manual storage heater controls to automatic charge control	33	£400	£13,200
CONTROLS - Upgrade to full zone controls (add room thermostat) from programmer and multiple room stats	3	£600	£1,800
CONTROLS - Upgrade to full zone controls (add room thermostat) from programmer TRVs and bypass	26	£600	£15,600
CONTROLS - Upgrade to full zone controls (TRVs, programmer room thermostat) from no controls	12	£600	£7,200
CONTROLS - Upgrade to full zone controls (TRVs, programmer) from single programmer and room thermostat only	23	£600	£13,800
CONTROLS - Upgrade to full zone controls (TRVs, room thermostat) from single programmer only	70	£600	£42,000
CONTROLS - Upgrade to full zone controls from full normal controls set	46	£600	£27,600
DRAUGHTS - Fit baffles to block open chimneys when not in use	330	£77	£25,250
FLOORS - Add 50mm or equivalent insulation to pre 1996 solid floor	5	£2,084	£10,420
FLOORS - Add 50mm or equivalent insulation to pre 1996 suspended timber floor	5	£2,139	£10,693
FLOORS - Externally insulate exposed floor	4	£4,000	£16,000
HEATING DATA - Add actual PCDF boiler reference to RdSAP data using an average boiler for the known category	883	£0	£0
HEATING FUEL - Replace bottled LPG with bulk LPG	74	£500	£37,000
HEATING SYSTEM - Decommission Electric ceiling heaters, replace with fan storage heaters	8	£2,500	£20,000
HEATING SYSTEM - Decommission Electric ceiling heaters, replace with gas combi (gas near or in property)	28	£5,500	£154,000
HEATING SYSTEM - Decommission Electricaire, replace with fan storage heaters	1	£2,500	£2,500
HEATING SYSTEM - Decommission Electricaire, replace with gas combi	7	£5,500	£38,500
HEATING SYSTEM - Replace electric boiler with A rated combi system, Gas connection distance unknown	2	£5,000	£10,000
HEATING SYSTEM - Replace electric boiler with A rated combi system, Gas in property	2	£3,300	£6,600
HEATING SYSTEM - Replace electric boiler with A rated combi system, Gas near property	4	£5,500	£22,000
HEATING SYSTEM - Replace electric boiler with fan storage heaters	47	£2,500	£117,500
HEATING SYSTEM - Replace electric heaters with A rated combi system, Gas in property	187	£3,300	£617,100
HEATING SYSTEM - Replace electric heaters with A rated combi system, Gas near property	170	£5,500	£935,000
HEATING SYSTEM - Replace electric heaters with fan storage heaters, Gas distance unknown	19	£2,500	£47,500
HEATING SYSTEM - Replace electric heaters with fan storage heaters, No gas near	2	£2,500	£5,000
HEATING SYSTEM - Replace Storage Heaters with A rated combi system, Gas in property	13	£3,300	£42,900
HEATING SYSTEM - Replace Storage Heaters with A rated combi system, Gas near property	25	£5,500	£137,500
HEATING SYSTEM - Upgrade C rated gas combi to A rated combi system with FGHRS	1	£2,500	£2,500
HEATING SYSTEM - Upgrade C rated LPG boiler to A rated LPG combi	8	£3,500	£28,000
HEATING SYSTEM - Upgrade community heating to Gas CHP, upgrade controls	1	£2,500	£2,500
HEATING SYSTEM - Upgrade E rated LPG boiler to A rated LPG combi	4	£3,500	£14,000
HEATING SYSTEM - Upgrade E rated oil boiler to A rated oil combi	1	£3,500	£3,500
HEATING SYSTEM - Upgrade electric underfloor storage heating in concrete slab to fan storage heaters	4	£2,500	£10,000
HEATING SYSTEM - Upgrade electric underfloor storage heating in screed to fan storage heaters	7	£2,500	£17,500
HEATING SYSTEM - Upgrade F equivalent solid fuel boiler to A rated oil combi	2	£3,500	£7,000
HEATING SYSTEM - Upgrade F rated gas combi to A rated combi system with FGHRS	1	£2,500	£2,500
HEATING SYSTEM - Upgrade F rated LPG boiler to A rated LPG combi	25	£3,500	£87,500
HEATING SYSTEM - Upgrade G rated gas combi to A rated combi system with FGHRS	2	£2,500	£5,000
HEATING SYSTEM - Upgrade G rated LPG boiler to A rated LPG combi	48	£3,500	£168,000
HEATING SYSTEM - Upgrade gas room heaters to new central heating with combi	12	£3,300	£39,600
HEATING SYSTEM - Upgrade LPG room heater to new LPG combi	6	£3,500	£21,000
HEATING SYSTEM - Upgrade modern slimline storage heaters to fan storage heaters	27	£2,500	£67,500
HEATING SYSTEM - Upgrade oil room heaters to new oil central heating with combi	3	£5,000	£15,000

Initiative	Number of measures	Estimated average cost per SAP point per home	Total investment
HEATING SYSTEM - Upgrade old storage heaters to ASHP	7	£7,500	£52,500
HEATING SYSTEM - Upgrade old storage heaters to fan storage heaters	6	£2,500	£15,000
HEATING SYSTEM - Upgrade regular E rated gas boiler to A rated combi system with FGHRS	1	£2,800	£2,800
HEATING SYSTEM - Upgrade regular G rated gas boiler to A rated combi system with FGHRS	8	£2,800	£22,400
HEATING SYSTEM - Upgrade slimline storage heaters to ASHP	7	£7,500	£52,500
HEATING SYSTEM - Upgrade slimline storage heaters to GSHP	1	£11,000	£11,000
HEATING SYSTEM - Upgrade solid fuel room heaters to new oil central heating with combi	28	£5,000	£140,000
HOT WATER - Check or upgrade inaccessible cylinder to 80mm jacket	149	£16	£2,384
HOT WATER - Retrofit WWHRS in suitable shower or shower and bath rooms	297	£657	£195,150
HOT WATER - Single to dual immersion	153	£750	£114,750
LIGHTING - Upgrade remaining inefficient lighting	115	£155	£17,875
OPENING DRAUGHTS - Draughtproof all doors and windows	662	£53	£35,119
ROOF - Add loft insulation to uninsulated thatched roof	1	£350	£350
ROOF - Check or add insulation to loft with unknown insulation	38	£301	£11,450
ROOF - Insulate loft from 0mm to 300mm	756	£350	£264,600
ROOF - Insulate loft from 100mm to 300mm	22	£300	£6,600
ROOF - Insulate loft from 12mm to 300mm	63	£300	£18,900
ROOF - Insulate loft from 150mm to 300mm	4	£300	£1,200
ROOF - Insulate loft from 250mm to 300mm	2	£300	£600
ROOF - Insulate loft from 25mm to 300mm	16	£300	£4,800
ROOF - Insulate loft from 50mm to 300mm	43	£300	£12,900
ROOF - Insulate loft from 75mm to 300mm	14	£300	£4,200
SECONDARY HEATING - Remove secondary gas heaters	33	£250	£8,250
SECONDARY HEATING - Remove secondary non-portable electric heaters	107	£200	£21,400
SECONDARY HEATING - Remove secondary portable electric heaters	54	£200	£10,800
SECONDARY HEATING - Remove secondary solid fuel heaters	41	£250	£10,250
TARIFF SWITCH - Switch tariff from single to dual	524	£0	£0
WALLS - Cavity wall insulation to 1976-1982 cavity wall	7	£700	£4,900
WALLS - Cavity wall insulation to 1983-1995 cavity wall	1	£700	£700
WALLS - Cavity wall insulation to pre 1976 cavity wall	144	£700	£100,800
WALLS - Insulate 1900-1966 timber frame walls internally	5	£5,507	£27,535
WALLS - Insulate Airey system house externally (assuming no additional structural work needed)	1	£12,008	£12,008
WALLS - Insulate pre 1976 solid walls externally	82	£6,148	£504,157
TOTAL			**£4,291,739**
AVERAGE INVESTMENT			**£1,421**

Figure 14: Selected measures applied over the sampled stock to achieve a minimum SAP score of 39

Appendix F: Other documents provided with this report

Minimum EPC standards report WWF and UK-GBC v1pt3 Data Summary.xlsx

Detailed results summary for the options analysis described in section 4, presented as a sortable spreadsheet.

Data used to produce selected charts in this report.

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