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Developing the regulation of energy efficiency of private sector housing (REEPS): modelling improvements to the target stock

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DEVELOPING REGULATION OF ENERGY EFFICIENCY OF PRIVATE SECTOR HOUSING: MODELLING IMPROVEMENTS TO THE TARGET STOCK

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EXECUTIVE SUMMARY

Introduction

In June 2013, the Scottish Government published the Sustainable Housing Strategy, which set out its commitment to consult on draft regulations that would set minimum energy efficiency standards for private sector houses.

Energy efficiency standards for housing in the social rented sector have been in place since 2004. In contrast there has been limited regulation of existing private sector dwellings to date. Meeting the 'Tolerable Standard[1]' does include minimum requirements for thermal insulation and heating and while there are regulations relating to the construction of new build housing and extensions, those relating to existing homes have been restricted to specific improvement works if and when they are undertaken.

The Regulation of Energy Efficiency in Private Sector homes (REEPS) working group was set up to oversee the development of the draft regulations.This research was commissioned to support the work of the REEPS technical subgroup.

The target stock

The Scottish Government's approach to assessing the energy efficiency of houses is the Standard Assessment Procedure (SAP). SAP ratings are the basis of the bandings shown on Energy Performance Certificates (EPCs) that are required to be produced when dwellings are sold or let.

Private sector stock is less energy efficient than social housing. Overall, 23% of the private sector stock falls within the lowest three SAP EPC bands of E, F and G. This equates to 400,548 dwellings. These were the focus of the research.

The target stock includes a higher prevalence of detached dwellings, older dwellings, dwellings with a solid stone wall construction, and dwellings that do not use mains gas or electricity as their main source of energy. They are also less likely to have access to a mains gas connection. Dwellings in rural Scotland are more likely than those in urban areas to be in the lowest EPC bands, bands E, F and G.

19% of REEPS target stock is privately rented, with higher proportions of private rented dwellings in the lowest EPC band ratings of G and F.

The aims and methods of the research

The research project was established to address the question: 'What are the most effective ways to increase the energy efficiency of the Scottish private sector dwelling stock in EPC bands E, F and G?'

[1] Source: Implementing the Housing (Scotland) Act 2006, Parts 1 and 2: Advisory and Statutory Guidance for Local Authorities: Volume 4 Tolerable Standard : http://www.gov.scot/Publications/2009/03/25154751/0

The project modelled existing data from the Scottish House Condition Survey (SHCS) from 2010 to 2012, and comprised three broad phases. Phase 1 of the research involved:

- developing a typology of the private sector housing stock in EPC bands EFG using data from the SHCS.
- identifying associated archetypes in the data, e.g. dwellings that would represent each typology group.
- identifying the appropriate potential energy efficiency improvement measures.
- outlining principles for constructing a hierarchy of measures to create packages that would reach minimum thresholds of energy efficiency.
- outlining methods for determining the costs of measures.

Developing the typology involved segmenting the data into similar dwellings in relation to the technical feasibility of improvement measures and likely gains in energy efficiency. Overall, 355 typology groupings were created with each representing around 1,100 dwellings on average (0.3% of the target stock).

In the second phase, the suitability, cost and impact of 38 potential improvements were assessed for each archetype. These were collated from a wide variety of sources and covered insulation, ventilation, heating, hot water, space and water heating controls, renewables, and other energy saving improvement options. Various impacts of measures were modelled including impact on energy efficiency (SAP rating); impact on CO_{2e}; impact on primary and delivered energy; and cost effectiveness.

A key concern for the implementation of improvement measures is cost effectiveness. Indicative capital costs for each of the improvement measures were identified usually from the Product Characteristics Database File (PCDF) embedded within SAP software, and updated at regular intervals on behalf of the government. This is the standard set of reference costs used by SAP and by Green Deal assessments. Alternative sources of costs were investigated as part of the research.

As well as assessing individual measures, packages of measures to take each dwelling into the successive SAP bandings were identified and assessed. In the final phase, a number of policy scenarios were assessed.

A wide variety of technical issues were raised during the lifetime of this project in relation to methodology and assumptions used in the modelling. These included concerns relating to traditional buildings, the SAP methodology, and how costs are determined. The research also summarises these issues.

Findings

Four policy scenarios were modelled to explore the most effective ways in which to increase the energy efficiency of the private sector stock in EPC bands EFG.

- Scenario 1: improving all dwellings to reach EPC Band F

- Scenario 2: improving all dwellings to reach EPC Band E
- Scenario 3: improving all dwellings to reach EPC Band D
- Scenario 4: improving all target dwellings to move up one banding

The following table summarises the key results.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	All to reach Band F	All to reach Band E	All to reach Band D	All up one band
Number of dwellings improved	29,676	170,708	400,548	400,548
Mean SAP score increase from improvements	13.7	13.4	16.4	9.4
Mean capital cost	£627	£1,232	£2,672	£969
Overall capital cost	£18.6 m	£210.2 m	£1,070.2 m	£388.1 m
Mean reduction in fuel cost pa	£542	£463	£483	£279
Overall reduction in fuel cost pa	£16.1 m	£79.0 m	£193.0 m	£111.6 m
Mean reduction in CO2 pa	2,113 kg	2,119 kg	2,617 kg	1,515 kg
Overall reduction in CO2 pa	62.7 k tons	362k tons	1046k tons	606k tons
Mean reduction in Primary Energy pa	10,313 kWh	9,894	12,583	7,424
Overall reduction in Primary Energy pa	306 m kWh	1,689 m	5,030 m	2,968 m
Mean reduction in Delivered Energy pa	6,889 kWh	7,460	8,911	5,105
Overall reduction in Delivered Energy pa	204 m kWh	1,273 m	3,569 m	2,044 m
Median payback period	1.1 years	2.3	3.8	2.5
Mean cost per SAP point increase	£46	£92	£163	£103

In terms of the scale of the different packages of measures, Scenarios 3 and 4 affect more dwellings than do the other 2:

- 29,676 dwellings would be improved by Scenario 1;
- 170,708 dwelling would be improved by Scenario 2;
- 400,548 dwellings would be improved by Scenarios 3 and 4.

Modelling results were further split by tenure (ie owner-occupied and private rented dwellings), by urban and rural locality and profiled over the next 30 years based on turnover of house sales and rental of properties.

Dwellings in rural areas tend to be less energy efficient than those in urban areas. The majority of dwellings affected by Scenarios 1 and 2 would be in rural areas (67% and 59% respectively) while 42% of dwellings affected by Scenarios 3 and 4 would be in rural areas.

19% of REEPS target stock is privately rented although a higher proportion of private rented dwellings are in the lowest EPC band ratings of G and F. Implementation will be linked to the letting of private rented properties and the sale of owner occupied dwellings. As turnover rates are considerably higher among privately rented dwellings, this sector will account for most of the target stock in the first few years of REEPS. After 3 years, private rented dwellings will account for 81% of dwellings in Scenario 1, 67% in Scenario 2 and 62% in Scenarios 3 and 4.

The average capital cost of improvements per dwelling reflects both how much each dwelling needs to be improved and the base position of the dwelling. Packages of improvements that make a large increase in energy efficiency are, on average, more expensive than those that make a small increase. The average cost of investments per dwelling in Scenario 1 is £627, Scenario 2 is £1,232, Scenario 3 is £2,672 and for Scenario 4 it is £969.

The more efficient dwellings are, the more expensive they are to improve further. The average cost of improving a dwelling in EPC band G by one band is £627 compared to £1,062 for a dwelling in EPC band E.. A similar pattern is seen with regard to cost per SAP point increase: £46 for G to F, to £126 for E to D.

The overall capital cost of improving all dwellings under each scenario is as follows:

- Scenario 1 (to reach EPC band F) would require £18.6 million
- Scenario 2 (to reach EPC band E) would require £210 million
- Scenario 3 (to reach EPC band E) would require £1,070 million
- Scenario 4 (all up one band) would require £388 million

The average cost of improvements tends to be higher for dwellings in rural areas than dwellings in urban areas across all Scenarios. This difference is most marked for Scenario 3 - £4,092 compared to £1,656 – primarily because of the higher proportion of rural dwellings in EPC bands G and F.

Measures included in packages and policy scenarios

The total number and proportion of dwellings with specific measures included within their package of measures to bring properties up to different standards, varied across the scenarios. The three most common measures under each scenario were:

- Scenario 1 (to reach EPC band F): Loft insulation including top-up (18,375 or 62%), Hot water tank jacket (4,651 or 16%), Room thermostat (4,457 or 15%),
- Scenario 2 (to reach EPC band E): Loft insulation including top-up (74,369 or 44%), Low energy lighting (25,496 or 15%), Cavity Wall Insulation (24,611 or 14%),
- Scenario 3 (to reach EPC band D): Loft insulation including top-up (157,256 or 39%), Low energy lighting (135,662 or 34%), Cavity Wall Insulation (103,250 or 26%),
- Scenario 4 (all up one band): Loft insulation including top-up (133,380 or 33%), Low energy lighting (101,310 or 25%), Hot water tank jacket (62,406 or 16%).

There were some differences by rurality, particularly in relation to Scenario 3. A higher proportion of dwellings in rural areas than in urban areas have room in the roof insulation, floor insulation and the replacement Oil/LG Boilers in the package of measures to reach EPC band D. In contrast, low energy lighting was more commonly included in urban than in rural areas. There was very little difference in the measures included in the packages by tenure.

Impact of packages and policy scenarios

In terms of overall savings in relation to fuel costs, CO_{2e} emissions and Primary and Delivered Energy consumption, Scenario 1 has the smallest impact and Scenario 3 has the largest impact due to the difference in terms of number of dwellings improved and scale of the improvements required. Generally, however, the more efficient a dwelling is pre-improvement measures; improvements will have a smaller impact.

The overall impact with regard to annual fuel cost savings of the different scenarios would be:

- Scenario 1 would give an annual fuel cost savings of £16.1million.
- Scenario 2, £79.0 million
- Scenario 3, £193.0 million
- Scenario 4, £111.6 million

For the least efficient dwellings, the capital cost of improvements is lowest, and the financial gains are highest. It follows that the payback period is the shortest for these dwellings. Scenario 1 has a mean payback period of 1.2 years, compared with 2.7 for Scenario 2, 5.5 for Scenario 3, and 3.5 year for Scenario 4.

Impact on overall annual CO_{2e} emissions:

- Scenario 1 would amount to annual savings of 63 thousand tons,
- Scenario 2 would give annual savings of 362 thousand tons,
- Scenario 3 would give annual savings of 1.05 million tons,
- Scenario 4 would give annual savings of 606 thousand tons.

The larger the scale of the improvement measure the greater the reduction in CO_{2e} emissions.

Impact in overall annual delivered and primary energy savings:

- Scenario 1 would lead to an annual saving of 204m kWh per annum for delivered energy and 306m kWh for primary energy.
- Scenario 2 leads to an annual saving of 1,273m kWh for delivered energy and 1,689m kWh for primary energy.
- Scenario 3 leads to an annual saving of 3,569m kWh for delivered energy and 5,030m kWh for primary energy.

- Scenario 4 leads to a savings of 2,044m kWh for delivered energy and 2,968m kWh for primary energy.

As with energy costs, the larger the scale of improvement made, the greater the impact. Furthermore, improving a dwelling by one band has a larger impact on the least efficient dwellings.

Individual improvement measures

The presence of energy saving features within a dwelling, the location of a dwelling, and whether the dwelling is on on/off the gas grid are important factors in determining the applicability of improvement measures and assessing their relative effectiveness in improving energy efficiency. Some improvement measures are cost effective but have little impact on SAP rating; certain measures are expensive and have little impact on SAP rating. There is a high degree of variability across the different improvement measures in terms of their relative impact in improving energy efficiency.

Individual measures were modelled for all dwellings where they were possible to implement and where they would potentially increase the SAP rating. Among the 38 improvement measures, nine improvement measures had a payback period of less than three years, though these varied in the size of their impact. Those with the shortest payback period were adding a hot water tank jacket, low energy light bulbs, switching electricity tariff, loft insulation, and installing thermostatic radiator valves (TRVs).

1 INTRODUCTION

1.1 In this section, we briefly outline the context of this report and overall structure of the research.

Policy Background

1.2 The Climate Change (Scotland) Act 2009 formally established in legislation the Scottish Government's ambitious target to cut the basket of 6 Kyoto Protocol greenhouse gas emissions by 42% by 2020 (compared to 1990/1995[2] base lines), and by 80% by 2050. Even before adopting this legislation, the Scottish Government had established a target to eradicate fuel poverty as far as reasonably practicable by 2016.

1.3 Within the social housing stock, the Scottish Government established minimum energy efficiency standards to be achieved by 2015 under the wider Scottish Housing Quality Standard (SHQS). Its successor, the Energy Efficiency Standard for Social Housing (EESSH), which is due to run from 2015 to 2020, sets out the energy efficiency standards that should be achieved within the social housing stock by 2020.

1.4 In June 2013, the Scottish Government published the Sustainable Housing Strategy, which set out a commitment to consult on draft regulations that would set minimum energy efficiency standards for private sector houses, including both the owner-occupied and private rented sectors. The only energy standards that had previously been set for private sector stock were through the Section 6: Energy standards (and their predecessor, the Part J standards) of the Scottish Building Regulations and the requirement to have loft insulation (if applicable) in the Tolerable Standard[3]. These apply to the construction of new build housing, extensions, and heating system replacements in the existing stock.

1.5 In order to consider issues around regulation and to help develop draft regulations for consultation, the Regulation of Energy Efficiency in Private Sector homes (REEPS) working group was set up. The main REEPS working group has been supported by two subgroups. The technical subgroup has been charged with examining technical measures to improve energy efficiency and how such measures will fit with regulation. The wider context subgroup was set up to consider issues around attitudes and behaviour in relation to energy efficiency, the relationship between incentives and regulation, and the wider impact of regulations on the housing market.

Overview of the project

1.6 This research was commissioned to support the REEPS technical sub-group to aid the development of the draft regulations for consultation. The main

[2] Different baselines were used for different gasses.
[3] Under the Guidance for the Tolerable Standard, it is the 'presence' of some roof insulation, rather than any specific thickness or standard across the roof space that is defined with the standard.

objective of the research was to examine potential policy options for raising the energy efficiency among the least energy efficient dwellings in the private sector housing stock by analysing and modelling data from the Scottish House Condition Survey (SHCS).

1.7 The research can be summarised as providing evidence to answer the following question:

> "What are the most effective ways to increase the energy efficiency of the Scottish private sector dwelling stock in EPC bands E, F and G?"

1.8 The work involved modelling of energy efficiency performance characteristics of a range of different types of property that were broadly representative of the target stock - private sector dwellings in EPC bands EFG. The study was designed to allow an appropriate set of improvement measures to be modelled and to assess them in terms of their impact on energy demand and carbon reduction potential, cost effectiveness and technical feasibility

1.9 The project comprised three broad phases. In phase 1 of the research, the objectives were to:

- Develop a typology of the private sector housing stock in EPC bands EFG using data from the Scottish House Condition Survey (SHCS).
- Identify associated archetypes in the data, e.g. dwellings that would represent each typology group.
- Identify the appropriate potential energy efficiency improvement measures.
- Outline principles for constructing a hierarchy of measures to create packages that would reach minimum thresholds of energy efficiency.
- Outline methods for determining the costs of measures.

1.10 In the second phase, the suitability and impact of the improvement measures were assessed for each archetype and the impact in relation to energy efficiency and related outcomes were assessed. The outcomes modelled included: energy efficiency (SAP rating); impact on CO_{2e} emissions; impact on primary and delivered energy; and cost effectiveness.

1.11 Finally, in the third phase, a number of policy scenarios were assessed using the modelled archetype data.

Structure of the report

1.12 Chapter 2 provides a summary of the target stock before improvement. Chapter 3 details how a typology of this stock was developed and how the associated archetypes were chosen. Chapter 4 discusses what energy efficiency improvement measures were considered appropriate, the principles underpinning the choice of a package of measures to reach the next EPC band, and the assumptions underpinning the costing of the measures. Chapter 5 provides the results, grossed to the target stock for different policy scenarios and details of the impact of the measures individually. Chapter 6 provides a commentary on a range of technical issues and related assumptions of relevance. This report also includes a number of technical appendices.

1.13 Accompanying this report are details of the 355 individual archetype dwellings that were modelled. These give information on the base position of each dwelling, the appropriateness and impact of individual improvement measures, the packages of measures modelled, and the impact of these packages across a variety of measures.

Acknowledgements

1.14 The authors take full responsibility for the content of this report, but gratefully acknowledge the contribution of a wide range of people who have provided support and guidance throughout.

1.15 The research was overseen by a Research Advisory Group (RAG) who played a major role in steering the work[4]. The authors would like to thank Adam Krawczyk, Jamie Robertson, Oscar Guinea and Valerie Sneddon at the Scottish Government for their continued input, advice and guidance throughout the study and to the other members of the REEPS groups that contributed to the research. We would also like to acknowledge the assistance and expert input from Dave Cormack, Scott Restrick, Marcus Sheldrick and Steven Hope.

1.16 Perhaps most of all however, we are grateful to the thousands of householders across Scotland who agree to take part in the Scottish House Condition Survey each year. Each gives up to an hour of their time to complete the social survey and also allow a surveyor to assess their property, externally and internally. Without their goodwill, this work would not have been possible.

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Bill Sheldrick

[4] See Appendix 12 for membership.

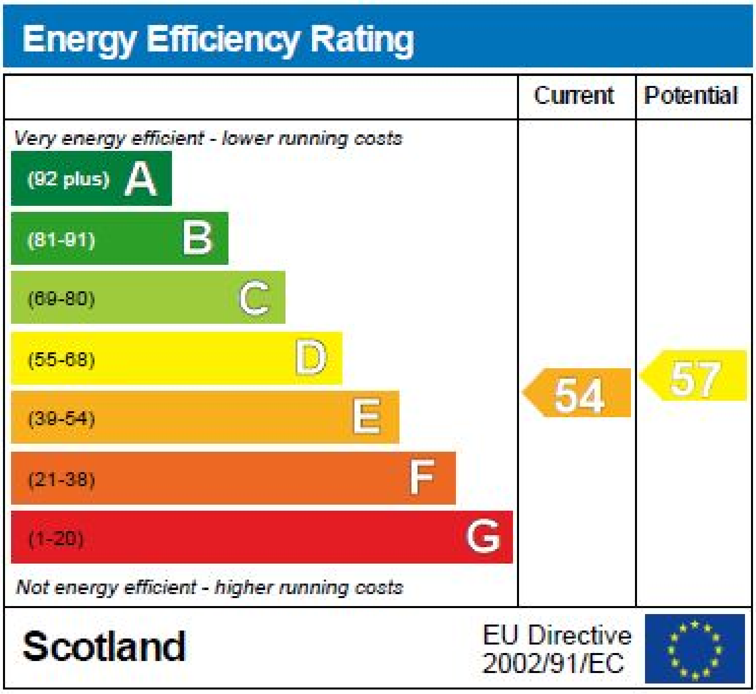
2 SUMMARY OF THE TARGET STOCK

2.1 In this section we provide a very brief overview of energy efficiency ratings, before giving an overview of the target stock - private sector dwellings in the lowest three EPC bands EFG - before improvements.

Overview of energy efficiency ratings of domestic dwellings in Scotland

2.2 Much like the rating of the efficiency of new electrical appliances, Energy Performance Certificates (EPCs) show the efficiency of buildings, with ratings ranging from A (very efficient) to G (inefficient). They show a current rating and a rating if improvements were made. All domestic buildings in the UK that become available to buy or rent must have an Energy Performance Certificate. An example is shown in Figure 2.1.

Figure 2.1: Example Energy Efficiency Rating from a standard Energy Performance Certificate (EPC).



2.3 EPC Energy Efficiency Ratings are underpinned by the SAP (Standard Assessment Procedure) methodology. As the name (partially) implies, this is a standard way of assessing the energy consumption of dwellings.

2.4 SAP works by assessing how much energy a dwelling will consume, when delivering a set level of comfort and service provision (with regard to heating, lighting etc.). This is based on standardised assumptions for occupancy and behaviour and enables a like-for-like comparison of homes. Related factors, such as fuel costs and emissions of carbon dioxide (CO2), can be calculated from the assessment.

2.5 SAP quantifies a dwelling's performance in terms of energy use per unit floor area. This is based on estimates of annual energy consumption for the provision of space heating, domestic hot water, lighting and ventilation combined. In a nutshell, the rating is determined by how well a dwelling holds energy (such as retaining heat, storing hot water etc.) and how efficient its systems are at providing heat, hot water, etc.

2.6 The SAP scale ranges from 1 (least energy efficient) to 100 (the most energy efficient). In Figure 2.1, the numbers in brackets are the corresponding SAP scores for each EPC band: EPC band G ranges from 1 to 20, F from 21 to 38, and E from 39 to 54. Thus the target stock, private sector dwellings in the lowest three EPC bands, equates to all private sector dwellings with a SAP score of 54 or below.

2.7 The SAP methodology has been constantly evolving. The impact of these changes to this research is summarised later on in this chapter while a fuller description is given in Chapters 4 and 6.

2.8 The analysis in this report is based on data from the Scottish House Condition Survey (SHCS). Data has been combined from the 2010, 2011 and 2012 surveys to provide sufficient sample sizes for analysis. The SHCS is designed to be representative of all dwellings in Scotland that are used as a main residence[5]. Estimating energy use has been at the core of the survey for almost two decades and SAP ratings have been calculated for all dwellings covered by the survey since 1996. A summary of the SHCS is provided in Appendix 1.

Energy efficiency profile of Scottish residential dwellings

2.9 There were around 2.4 million dwellings in the residential housing stock in Scotland used as a main residence over the 2010 to 2012 period. Around three quarters (74%) of these dwellings were in the private sector with 62% owner occupied and 12% privately rented.

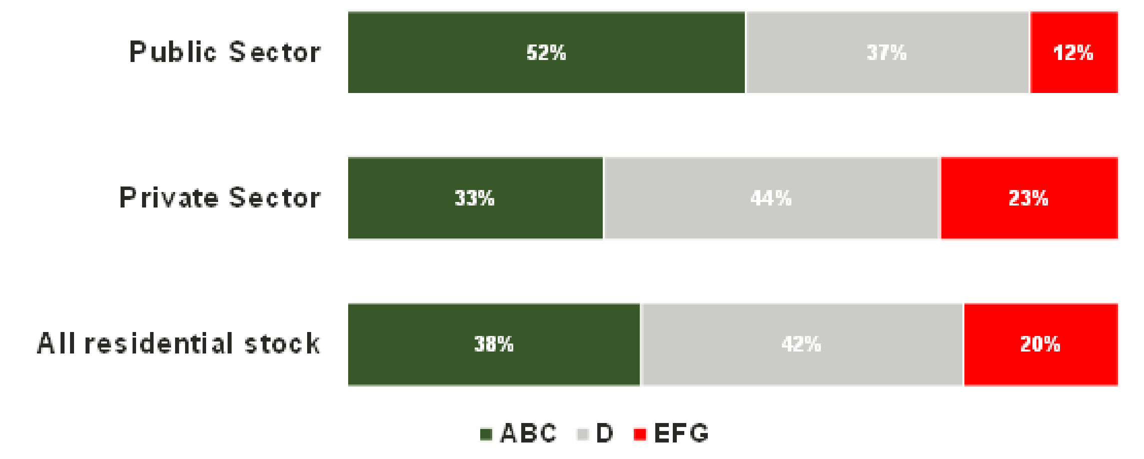
2.10 The energy efficiency of private sector housing stock overall was poorer than that of the public sector. Overall, 23% of private sector dwellings were in EPC bands EFG compared to 12% of public sector dwellings (Figure 2.2)[6].

2.11 This means that while 74% of dwellings are in the private sector, 85% of all dwellings in EPC bands EFG are in the private sector.

[5] It does not include vacant dwellings, dwellings that are used as second homes, or dwellings that are used for short-term holiday lets.

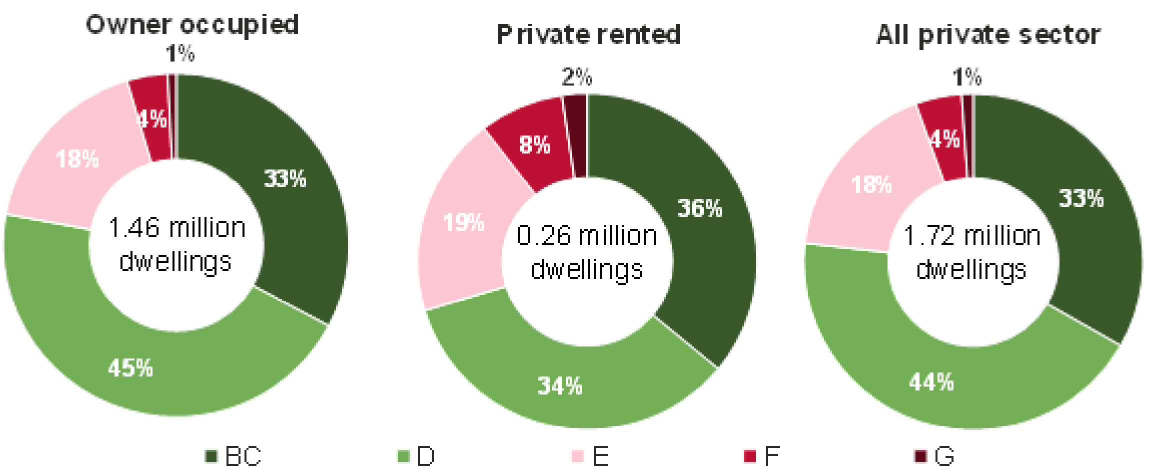
[6] All figures in this section are based on the SAP 2005 methodology. The evolution of the SAP methodology is discussed in the next section.

Figure 2.2: EPC bandings by sector



2.12 The difference in energy efficiency between the public and private sectors was also reflected in the average SAP scores. The median SAP score among all private sector dwellings is 64, compared to 69 among public sector dwellings.

Figure 2.3: Summary of EPC bandings by tenure breakdown within the private sector

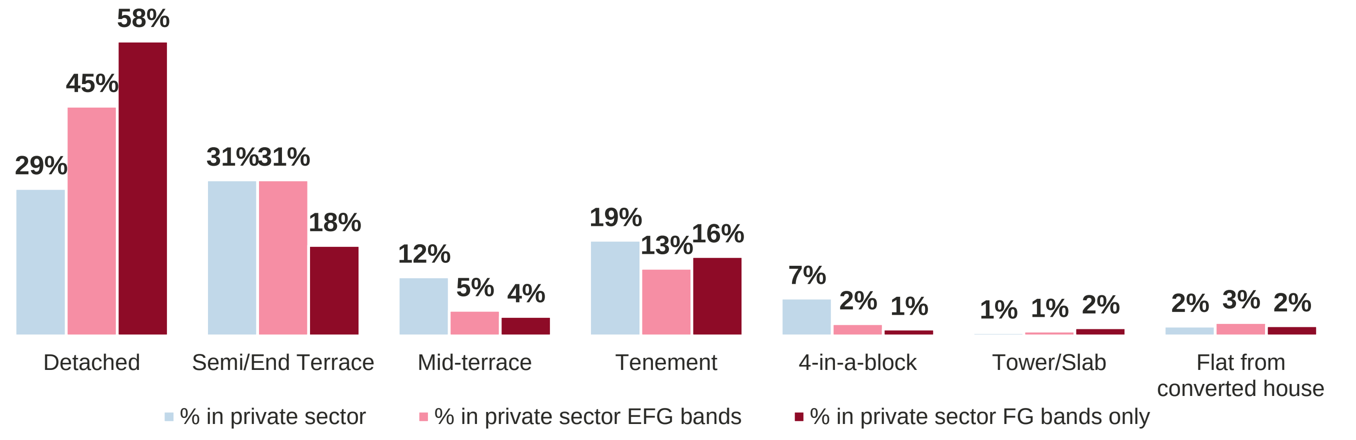


2.13 Figure 2.3 shows the distribution of EPC bandings within the private sector. A higher proportion of private rented dwellings than owner occupied dwellings were in EPC bands EFG (29% compared to 23%).Overall, 23% of the private sector residential stock was in the lowest three EPC bands, EFG. This equated to 400,548 dwellings.

2.14 As detailed in the next chapter, four key dwelling characteristics – dwelling type, dwelling age, wall type and heating type - that are closely associated with energy efficiency were used to create a typology of the REEPS target stock and to choose archetype dwellings for modelling potential improvements[7]. Below we summarise the make-up of the target stock with regard to these four characteristics.

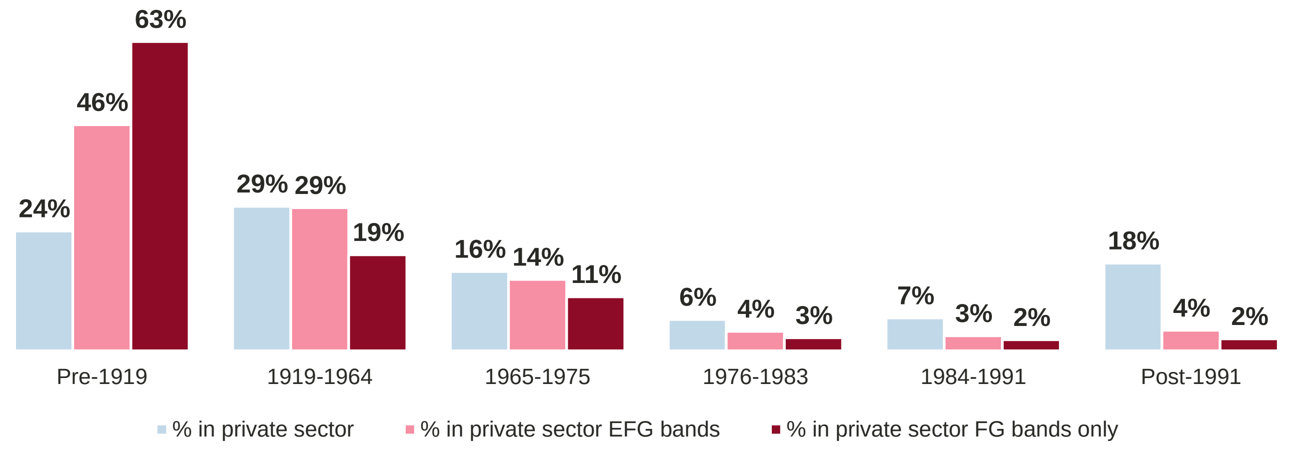
2.15 Figure 2.4 summarises private sector dwellings by dwelling type[8]. Detached properties tend to be less energy efficient than other dwelling types. While detached properties account for around 29% of all private sector dwellings, they account for 45% of dwellings in EPC bands EFG, and 58% of dwellings in EPC bands FG. (Tables A8.1 to A8.4 in Appendix 8 give further details of this breakdown and the number of dwellings).

Figure 2.4: Distribution of private sector dwellings by dwelling type



2.16 Semi-detached properties account for 31% of dwellings in EPC bands EFG, and 18% of those in bands FG. Tenements account for 13% of the target dwellings, and 16% in bands FG.

Figure 2.5: Distribution of private sector dwellings by NHER Age

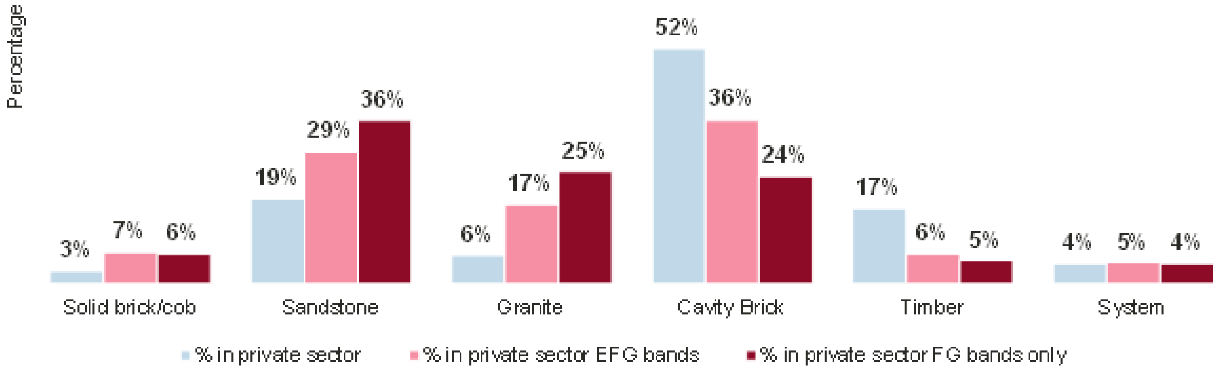


[7] The SHCS is designed so that these key characteristics match with the bandings in RdSAP
[8] The figures in this section are based on the SAP 2005 figures as SAP 2012 where only available for the modelled archetypes

2.17 Figure 2.5 shows a similar analysis by NHER age[9]. Older dwellings were much more likely to be energy inefficient than younger dwellings. Pre-1919 dwellings account for 46% of the target stock compared with 24% of the private sector stock overall. Additionally, pre-1919 dwellings accounted for almost two thirds (63%) of dwellings in the lowest two EPC bands, F & G. In contrast, only 11% of the target stock was post-1976 dwellings and only 7% of dwellings in the lowest two EPC bands were post-1976.

2.18 With regard to wall type, dwellings with cavity walls were more likely to be energy efficient than dwellings with solid walls. As shown in Figure 2.6, while dwellings classed as having cavity brick wall type[10] accounted for half the private sector dwellings (52%) in total, they only accounted for just over a third (36%) of the target stock, and only 24% of the EPC bands FG. By contrast, sandstone and granite/whinstone combined accounted for only 25% of all dwellings, but comprised 46% of the target stock and 61% of all dwellings in EPC bands FG. Solid brick/cob accounted for 7%, timber for 6% and system wall types for 5% of the target dwellings.

Figure 2.6 Distribution of private sector dwellings in EPC bands EFG by wall type



2.19 Figure 2.7 summarises private sector dwellings by their main heating systems[11]. While 77% of the private sector stock overall had a mains gas boiler, this type of heating was only present in 40% of dwellings in the target stock and only accounted for 9% of all dwellings in bands F and G. In contrast, other forms of heating, particularly electricity-based heating system, account for a larger proportion of dwellings in the lower EPC bands. For

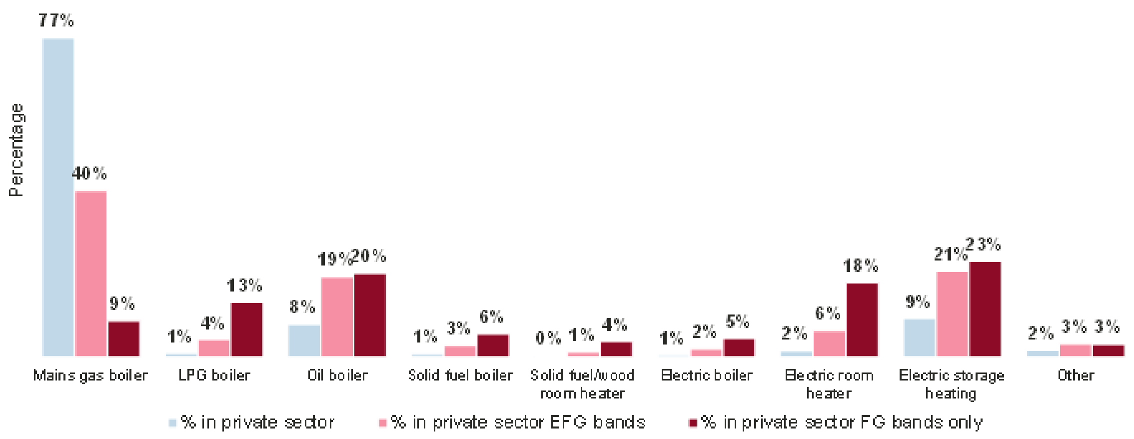
[9] For post-1964 aged properties, the NHER age is the "building warrant age" of a dwelling and is used to select the appropriate default U-values, given the Building Regulation standards applying at the time. For earlier periods, the dates reflect approximate changes in construction or housing legislation. For most cases, NHER age will be the same as the construction age banding, with the exception of conversions from non-domestic buildings or where considerable alterations have been made to the original dwelling. There will be a small number of dwellings however, where the Building Warrant was applied for just before a change in the energy efficiency standards and the dwelling built in the next construction age period.

[10] See Appendix 2 for details of the different wall types

[11] These fuel and heating combinations covered all cases found in the SHCS. Less prevalent types have been combined in Figure 2.6 but are expanded in the typology detailed and discussed in Section 3. Note that solid fuel boilers can use various types of coal or wood as fuel types.

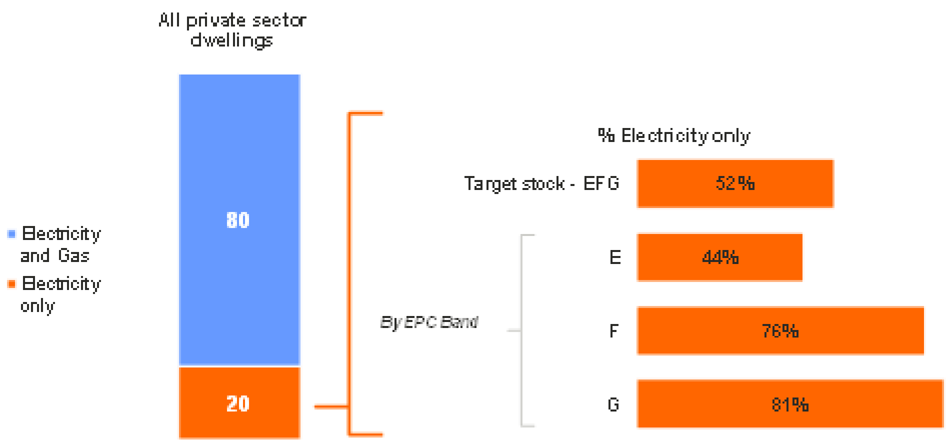
example, while peak electric room heaters were the main heating system[12] for only 2% of all private sector dwellings, they account for 6% of the target stock and 18% of dwellings in bands FG[13].

Figure 2.7: Summary of private sector dwellings in EPC bands EFG by heating type



2.20 The prevalence of different heating types is closely linked to access to mains gas (see Figure 2.8). Inefficient dwellings are more likely to lack access to mains gas. Across all private sector dwellings in Scotland, 20% of dwellings did not have access to mains gas[14]. Among the target stock, this proportion rose to 52%. Moreover, 76% of dwellings in EPC bands F and 81% of dwellings in band G did not have access to mains gas.

Figure 2.8: Summary of access to mains gas among all private sector dwellings and by EPC bands EFG



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[12] Main heating system is defined as the system that usually provides the heating to most rooms and the hot water. Where more than one system is present, the main heating is the one that heats the main living room. Where there is a system and individual room heaters present, then the room heaters are treated as secondary / supplementary heating appliances. Where there are only room heaters, the main heating is taken as the room heater heating the main living room. Electric storage heaters (even when there is only 1 storage heater) are considered in SAP & RdSAP to be a system.
[13] Electric peak room heating is the default within RdSAP where no heating system is present.
[14] SHCS 2010-2012,question L1 "What mains services does the dwelling have".

2.21 This prevalence of non-gas heating was also significantly different from the social rented sector where very little heating is not either mains gas or electric. The social sector has very little solid fuel or oil heated dwellings. This is not the case in the poorer performing dwellings in the private sector – 28% of all dwellings of the EFGs are using something other than gas or electric heating.

The evolution of SAP rating methodology

2.22 The methodology underpinning SAP is constantly being improved and refined. The original methodology, SAP 1998, has been replaced on a number of occasions, by SAP 2001, SAP 2005, SAP 2009, and SAP 2012 version 9.92.

2.23 At the start of the research project in May 2014, the latest available SHCS data was the 2010-2012 waves. (Three years of data were combined to allow robust sub-group analysis.) This data included the 2005 version of SAP. The initial stage of the research - estimation of the total size of the target stock, the development of a typology of dwellings and identifying associated archetypes in the data - used this version of SAP.

2.24 The latest version of SAP, SAP 2012 version 9.92, was released mid-way through the research project in December 2014. It was agreed with the REEPS RAG that the analysis of improvements and grossing of results should use this, the most up to date version of SAP.

2.25 A SAP 2012 score was calculated for all dwellings that were chosen to act as archetypes. Table 2.1 details the extent of the match between SAP 2005 and SAP 2012.

Table 2.1: Comparison breakdown of target stock by EPC band between SAP 2005 and SAP 2012 figures. (Total %ages)

		EPC Banding based on SAP 2012			
		E	**F**	**G**	**All**
EPC based on SAP 2005	**E**	214,172 (53%)	85,832 (21%)	5,996 (1.4%)	306,000 (76%)
	F	15,217 (4%)	52,240 (13%)	8,896 (2%)	79,353 (19%)
	G	451 (0%)	2,960 (1%)	14,784 (4%)	18,195 (5%)
	All	229,840 (57%)	141,032 (35%)	29,676 (7%)	400,548 (100%)

2.26 There was a reasonable match between the two versions with 70% being within the same EPC bandings. More dwellings were in EPC bands F and G using SAP 2012 than were using SAP 2005. In the final section of this chapter we summarise the distribution of the target stock using the SAP 2012 scores.

Size and distribution of the target stock

2.27 Table 2.2 summarises the SAP 2012 EPC banding profile among the target dwellings. The majority (57%) were in EPC band E, 35% are in EPC band F and 7% were in EPC band G.

Table 2.2: Breakdown of SAP 2012 EPC bands among private sector stock in bands EFG[15]

EPC Banding (SAP score)	Dwellings[16]	% of REEPS Target population	% of total Private Sector main residential dwellings[17]
E (39-54)	229,840	57.4%	13.2%
F (21-38)	141,032	35.2%	8.1%
G (Up to 20)	29,676	7.4%	1.7%
All	400,548	100%	23.1%

2.28 Around four-fifths of the target stock was owner-occupied (81%) with the remainder (19%) privately rented (Table 2.3). Privately rented dwellings were more prevalent in the lower bands - a higher proportion of dwellings in EPC bands G and F than in EPC band E were privately rented (40% and 21% compared to 16%).

Table 2.3: Breakdown of SAP 2012 EPC bands by tenure

	EPC Banding			
	G	**F**	**E**	**All GFE**
Owner Occupied	17,776 (60%)	110,904 (79%)	194,158 (84%)	322,838 (81%)
Private Rented Sector	11,900 (40%)	30,128 (21%)	35,682 (16%)	77,710 (19%)
All	29,676 (100%)	141,032 (100%)	229,840 (100%)	400,548 (100%)

2.29 Although 42% of the overall target stock is in rural areas, the proportions vary considerably by EPC band. (Table 2.4) Overall, 67% of G band properties and 57% of F band properties were in rural locations compared to 29% of E band properties.

[15] Based on SAP 2012
[16] This is a slight underestimate due to the 1.3% of cases with missing data on tenure.
[17] Based on 1.736 million private sector dwellings in Scotland. This is based on the grossing figure for SHCS 2010-2012 and only includes dwellings that are used as a main residence.

Table 2.4: Breakdown of SAP 2012 EPC bands by rurality

	EPC Banding			
	G	**F**	**E**	**All GFE**
Rural	19,910 (67%)	80,999 (57%)	66,149 (29%)	167,057 (42%)
Urban	9,767 (33%)	60,032 (43%)	163,692 (71%)	233,491 (58%)
Total	29,676 (100%)	141,032 (100%)	229,840 (100%)	400,548 (100%)

3 DEVELOPING A TYPOLOGY OF THE PRIVATE HOUSING STOCK IN EPC BANDS EFG

3.1 In this section, we describe the underlying principles and methods for creating the typology of the target stock. We then outline the typology groupings and how these were represented by archetype properties. Overall, the methods outlined resulted in 355 dwelling archetypes for modelling improvements.

Rationale underpinning the typology of the target stock

3.2 Fundamentally, developing a typology involved splitting the private sector housing stock in bands E, F and G into groupings of similar types of properties. Central to the creation of the typology groups was the need to minimise variation within groups.

3.3 One dwelling - an archetype – then had to be chosen to represent each typology grouping. Archetypes therefore had to represent all the dwellings within a typology group and needed to be an average example, typical of the typology group.

3.4 Given that the policy options had not been set at the time the typology groups were identified, the approach taken needed to allow a variety of potential options to be examined. The typology needed to cover as much as possible of the target stock – private sector dwellings in EPC bands E, F and G –and be designed to assess both where potential improvements could be made and the likely impact of improvements.

3.5 The assessment (and prioritisation) of potential improvement measures for each archetype followed a logical order:

- Is the measure technically feasible?[18]
- If yes, would it lead to gains in energy efficiency?
- If yes, how costly would it be to implement the measure?

3.6 Therefore, similarity between dwellings within a typology grouping had to be defined primarily in terms of characteristics that determine the technical feasibility of improvement measures and likely gains in energy efficiency, rather than, for example, characteristics that are more closely related to costs.

3.7 While dwellings with similar construction, insulation and heating characteristics were likely to have similar energy efficiency ratings regardless of floor size (SAP was designed to be insensitive to floor area), the reverse does not hold. Dwellings with similar energy ratings will vary considerably in terms of their form.

3.8 There are two potential approaches to constructing typologies: a top down approach, whereby the start-point is 100% of the target stock and this is then

[18] Consideration of the technical feasibility will include examining the risks associated with particular interventions. Measures are discussed in more detail in the next section.

continually sub-divided until reaching suitably homogenous groups; or a bottom up approach, where key segmentation variables are defined, all combinations of which are created, and then groupings are added together or split further.

3.9 Because of the importance of key build characteristics, a bottom-up two-stage approach was taken. The initial stage involved segmentation based on four key dwelling characteristics. In the second stage, relatively large groupings were then further sub-divided (by EPC band and in some instances size of dwelling) while groupings that accounted for a very small proportion of the target stock were combined back into more prevalent groupings.

3.10 The initial stage was to segment the dwelling stock on four key dwelling characteristics: dwelling type, dwelling age, wall type, and main heating type. These are key variables in RdSAP and their inclusion helped ensure that the typology groups were homogenous in relation to the technical feasibility of measures and likely gains in energy efficiency.

- **Dwelling type**: At one level built form is not important to the energy analysis of the dwelling stock, as the modelling was undertaken via a full SAP program (that does not use the built form to determine any of the dimensional details such as surface areas and heat loss characteristics of walls, floors and roofs which happens in RdSAP). However, built form is the way most people categorise and visualise the dwelling stock. It also acts as a good proxy for surface areas and heat loss characteristics of walls, floors and roofs. The distinction between houses and flats was also important in relation to assessing the cost of works.
- **Dwelling Age**: Building standards have tended to improve over time. Age is an essential variable within the RdSAP process because, when coupled with the wall construction or the floor construction, it determines the assignation of the respective default U-value[19]. It is also used to assign a U-value when the insulation levels of the dwelling are not known as well as helping to determine the default window area in houses and flats.
- **Wall type**: Wall construction is important factor in assigning the default U-value to a wall type, which then is a major determinant in the calculation of heat loss from the dwelling. Walls are usually the largest heat loss surface area in a dwelling. The wall construction is also a significant determinant in whether lower cost energy efficiency improvements (such as cavity wall insulation) can be undertaken on the property, or whether more expensive internal or external wall insulation is needed.
- **Main heating system**: The single most significant factor in determining the energy rating of a dwelling, its carbon emissions, and level of fuel bills is the combination of fuel and heating system efficiency. Highly efficient heating such as direct acting electric heating is expensive to run, and has a high CO_{2e} co-efficient attached to it. Similarly, there is a significant

[19] A U-value is a measure of heat loss. It shows the amount of heat lost per square metre of material - including various wall, roof and floor materials. The lower the u value, the better the insulation provided by the material.

difference in fuel bills for similarly efficient mains gas and LPG boilers because of the significant differences in the associated cost of fuel. Some cheaper to use fuels have a higher carbon co-efficient associated with them (such as solid fuel) compared to wood or biomass[20].

3.11 Some sub-categories of these four key characteristics were combined, where possible, before the initial typology was created. This was only undertaken on a limited number of categories to ensure that there was a low risk of grouping together dwellings with very different characteristics.

- **Dwelling type**: End-terraced houses were grouped with semi-detached houses, while enclosed end terraced houses were grouped with mid-terraced houses (both on the basis of number of party walls) to give 7 groups overall[21].
- **NHER ages** were combined into 6 bands based on the similarity of U-values amongst wall constructions. Further collapsing would have meant different default U-values for wall construction in RdSAP[22] in the same banding.
- **Wall type**: Cob (earth) wall type dwellings (that made up less than 0.5% of the target sock) were grouped with Solid Brick to give 6 bands[23].
- **Main heating type** was reduced into 13 bands by collapsing some of the rarer forms of heating that share common characteristics, e.g. all warm air systems were combined together, as were heat pumps regardless of whether they were using on or off peak electricity[24].

3.12 These four criteria were used as the basis for establishing the typology. When combined, 7 dwelling types, 6 NHER age bands, 6 wall type categories and 13 main heating forms give a theoretical total of 3,276 possible combinations. However, only 325 combinations existed in the SHCS data.

3.13 These 325 combinations differed considerably in their prevalence within the target stock:

- ***High prevalence***: 13 combinations each accounted for more than 1.5% of the target stock (over approximately 6,450 dwellings each) and 38% overall (153,500 dwellings).

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[20] It may seem contradictory that a highly efficient heating such as direct acting electricity heating is expensive to run and has a high CO2 co-efficient attached to it. This reflects the difference between the efficiency of the use of the heating system in the home (where electric heating is 100% efficient at converting electricity into space heating)and that the price of electricity and the associated CO2 emissions take account of amount of energy used to generate electricity at the power station (which is much less than 100% efficient) and its transportation to the home. Direct electric heating refers to the heating coming on at the touch of a button, compared to storage heating where the heat is stored over the night before you want to use it.

[21] Detached, Semi/End Terraced, Mid-terrace/Terrace with passage/Enclosed end, Tenement, 4-in-a-block, Tower/Slab, and Flat from converted house

[22] Pre-1919,1919-1964, 1965-1975, 1976-1983, 1984-1991, and Post-1991.

[23] Solid brick/Cob, Sandstone, Granite, Cavity Brick, Timber, and System.

[24] Mains Gas boiler, Mains gas room heater, Oil/Gas/Electric warm air, LPG boiler, Oil boiler
Solid fuel boiler, Solid fuel/wood room heater, Wood boiler, Electric peak/off-peak boiler, Electric peak room heater, Electric peak/off-peak heat pump, Off Peak Electric storage heating, Community Heating

- ***Medium prevalence***: 29 combinations each covered between 0.5% and 1.5% of the target stock (between approximately 2,000 and 6,000 dwellings) and 26% overall (102,200 dwellings).
- ***Low prevalence***: 126 combinations each covered between 0.1% and 0.5% of the target stock (between approximately 400 to 1,950 dwellings) and 27% overall (110,250 dwellings).
- ***Very low prevalence***: 157 combinations covered less than 0.1% of the target stock each (less than 400 dwellings) and 9% overall (34,600).

3.14 The high, medium and low prevalence combinations were further split while the very low prevalence combinations were collapsed in with the most similar grouping among the higher prevalence groupings where possible.

3.15 The high prevalence combinations were further split by up to four SAP 2005 score bandings - upper EPC band E (SAP 47-54), lower band E (SAP 39-46)[25], F (21-38) and G (20 and below) - and by 2 floor size bands[26]. Overall, this gave 76 sub-groupings among the 9 high prevalence combinations (as shown in Table 3.1).

3.16 To illustrate, the most prevalent dwelling combination, as shown at the top of Table 3.1, was pre-1919 detached houses with solid granite walls and an oil-boiler based heating system. These accounted for 5% of the target stock (19,000 dwellings). These dwellings were further sub-divided into 6 sub-groups - two different floor sizes[27] within three EPC groupings, upper E, lower E, and band F - each to be included in the final typology and each with a different archetype. Note that none of the cases in the data for this combination of building characteristics were in EPC band G.

Table 3.1: Summary of the high prevalence combinations and proposed sub-groups

Initial combinations	Further split	Total sub-groups	Dwellings (%age of target stock)	Sample size	%age in Upper E (47-54)	%age in lower E (39-46)	%age in F	%age in G
Pre-1919-Detached-Granite-Oil boiler	x3 EPC bands, x2 Size	6	19,900 5%	59	20%	44%	36%	
Pre-1919-Detached--Sandstone-Oil boiler	X4 EPC bands, x2 Size	7[28]	17,800 4.4%	104	28%	38%	33%	1%
1919-1964-Detached-Cavity Brick-Mains Gas boiler	x3 EPC bands, x2 Size	6	17,700 4.4%	71	75%	20%	5%	
1919-1964-Semi/End Terraced-Cavity Brick-Mains Gas boiler	x2 EPC bands, x2 Size	4	14,850 3.7%	64	96%	4%		
Pre-1919-Semi/End	x3 EPC bands,	6	13,200	48	72%	23%	5%	

[25] This was to account for the high proportion of target dwellings in EPC band E.
[26] Except for groupings with a small sample size
[27] Dwellings closest to the 33% and 67% percentile of floor size will therefore have been chosen as the archetypes
[28] As there was only one dwelling in EPC band G

Terraced--Sandstone-Mains Gas boiler	x2 Size		3.3%					
1965-1975-Detached-Cavity Brick-Mains Gas boiler	x3 EPC bands, x2 Size	6	12,300 3.1%	53	77%	19%	5%	
Pre-1919-Detached--Sandstone-Mains Gas boiler	x3 EPC bands, x2 Size	6	11,550 2.9%	44	39%	43%	17%	
Pre-1919-Tenement-Sandstone-Electric peak room heater	x4 EPC bands, x2 Size	8	8,950 2.2%	26	12%	16%	48%	25%
Pre-1919-Tenement-Sandstone-Mains Gas boiler	x2 EPC bands, x2 Size	4	8,050 2.0%	22	65%	35%		
Pre-1919-Detached--Granite-Mains Gas boiler	x3 EPC bands, x2 Size	6	7,950 2.0%	29	59%	33%	7%	
1965-1975-Semi/End Terraced-Cavity Brick-Mains Gas boiler	x2 EPC bands, x2 Size	4	7,750 1.9%	29	93%	7%		
1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating	x3 EPC bands, x2 Size	6	7,050 1.8%	29	47%	32%	21%	
Pre-1919-Detached--Granite-Off Peak Electric storage heating	x4 EPC bands, x2 Size	8	6,450 1.6%	19	3%	23%	58%	16%

3.17 The 29 medium prevalence combinations were further split into up to 4 separate typology groups based on the EPC bandings (with EPC band E split again into upper and lower). This resulted in 79 typology groupings. These are detailed in Table 3.2.

Table 3.2: Summary of the medium prevalence combinations and proposed sub-groups

Initial combination	Further split	Sub-groups	Dwellings (%age of target stock)	Sample size	%age in Upper E (47-54)	%age in lower E (39-46)	% in F	% in G
1965-1975-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating	x3 EPC bands	3	5700 1.4%	29	56%	35%	9%	
Pre-1919-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler	x2 EPC bands	2	5450 1.4%	25	73%	27%		
Pre-1919-Semi/End Terraced-Granite-Mains Gas boiler	x3 EPC bands	3	5450 1.4%	21	62%	28%	10%	
1919-1964-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler	x2 EPC bands	2	5150 1.3%	18	87%	13%		
Pre-1919-Flat from converted house-Sandstone-Mains Gas boiler	x3 EPC bands	3	5100 1.3%	20	43%	45%	12%	
1919-1964-Detached--Cavity Brick-Oil boiler	x3 EPC bands	3	5000 1.2%	46	51%	41%	8%	
1965-1975-Detached-Cavity Brick-Oil boiler	x3 EPC bands	3	4950 1.2%	36	44%	52%	4%	
Pre-1919-Tenement-Sandstone-Off Peak Electric storage heating	x3 EPC bands	3	4450 1.1%	14	56%	16%	28%	

Initial combination	Further split	Sub-groups	Dwellings (%age of target stock)	Sample size	%age in Upper E (47-54)	%age in lower E (39-46)	% in F	% in G
Pre-1919-Semi/End Terraced-Sandstone-Oil boiler	x3 EPC bands	3	4400 1.1%	25	59%	23%	19%	
Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage	x4 EPC bands	4	4250 1.1%	24	23%	50%	23%	5%
Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler	x4 EPC bands	4	3950 1.0%	14	24%	43%	25%	9%
1919-1964-Tenement-Cavity Brick-Mains Gas boiler	x2 EPC bands	2	3850 1.0%	12	67%	33%		
Pre-1919-Semi/End Terraced-Granite-Off Peak Electric storage heating	x3 EPC bands	3	3550 0.9%	9	13%	65%	22%	
Pre-1919-Detached--Sandstone-Off Peak Electric storage heating	x4 EPC bands	4	3400 0.9%	36	10%	22%	62%	6%
1919-1964-Semi/End Terraced-Cavity Brick-Oil boiler	x2 EPC bands	2	3200 0.8%	15	89%	11%		
1919-1964-Detached-Solid brick/Cob-Mains Gas boiler	x3 EPC bands	3	3150 0.8%	15	48%	42%	10%	
Pre-1919-Tenement-Sandstone-Means gas room heater	x3 EPC bands	3	2650 0.7%	8	60%	21%	19%	
Pre-1919-Detached-Sandstone-LPG boiler	x2 EPC bands	2	2600 0.6%	11			25%	75%
1976-1983-Detached-Cavity Brick-Oil boiler	x2 EPC bands	2	2600 0.6%	17	76%	24%		
Pre-1919-Tenement-Granite-Off Peak Electric storage heating	x3 EPC bands	3	2550 0.6%	9	50%	48%	1%	
Pre-1919-Semi/End Terraced-Granite-Oil boiler	x3 EPC bands	3	2550 0.6%	10	48%	2%	50%	
1919-1964-Detached-Cavity Brick-Off Peak Electric storage heating	x3 EPC bands	3	2500 0.6%	17	26%	44%	30%	
1965-1975-Detached-Cavity Brick-Off Peak Electric storage heating	x4 EPC bands	4	2450 0.6%	21	15%	31%	42%	12%
1919-1964-Tenement--Cavity Brick-Off Peak Electric storage heating	x3 EPC bands	3	2400 0.6%	7	74%	11%	15%	
1919-1964-Semi/End Terraced-System-Mains Gas boiler		1	2400 0.6%	12	100%			
1919-1964-Detached-Granite-Mains Gas boiler	x2 EPC bands	2	2350 0.6%	7	77%	23%		
1919-1964-4-in-a-block-Cavity Brick-Mains Gas boiler	x2 EPC bands	2	2100 0.5%	8	83%	17%		
1919-1964-Mid-ter/Ter with passage-Cavity Brick-Off Peak Elec storage	x2 EPC bands	2	2050 0.5%	8	66%	34%		
1919-1964-Semi/End Terraced-Timber-Mains Gas boiler	x2 EPC bands	2	2000 0.5%	6	68%	32%		

3.18 The 126 low prevalence combinations, that accounted for between 0.1% and 0.5% of the target stock (400 to 1,950 dwellings), were split into a maximum of three sub-groupings based on the EPC bands. (These are detailed in Appendix 4.) This was a similar approach to the medium prevalence combinations but did not make a distinction between dwelling in upper and lower halves of band E. Note, however, that many of these combinations only have dwellings in one EPC band and overall, this resulted in 188 archetypes.

Collapsing the very low prevalence typology groups into higher prevalence groups

3.19 The 157 very low prevalence combinations are detailed in Appendix 5. Given that each of these only account for a very small proportion of target stock - each less than 0.1% of the target stock (500 dwellings) and 9% overall - these were not modelled separately. Instead, they were collapsed backed into similar archetypes among the more prevalent groupings.

3.20 Central to the approach used to segment the target stock into archetype groups was the minimisation of variation within groups. This was also central to the approach taken to grouping the very low prevalent typology groups into similar archetypes among the more prevalent groupings.

3.21 A key consideration was the relative importance of the four building characteristics used to create the initial groupings - age and type of dwelling, wall type and heating type – plus EPC in this matching process. As heating type and wall type were more closely related to the feasibility of different technical improvements than dwelling type and dwelling age, and more important in determining energy efficiency ratings, these factors were prioritised.

3.22 A three-stage approach was undertaken:

- **Stage 1**: Relax house type (to house/flat) and age band of dwelling criteria. Match with a more prevalent typology group if heating type AND wall type AND EPC banding AND broad dwelling type can be matched. If possible, also match on either age band of dwelling OR dwelling type. Overall, 81 of the 157 very low prevalence groups were matched in this way. They accounted for 5% of the target stock overall.
- **Stage 2**: Match with a more prevalent typology group if they share EPC banding and EITHER wall type OR fuel type. If possible, also match on broad dwelling type (house/flat) and age band of dwelling where possible. Overall, 43 of the very low prevalence groups (3% of the REEPS target stock) were matched in this way.
- **Stage 3**: The remaining 33 very low prevalence groups accounted for less than 2% of the target stock. These were individually inspected. Overall, 9 of these were collapsed into more prevalent archetypes while an additional 12 archetypes were modelled to cover the remaining 24 very low prevalence groups.

3.23 In total, 355 typology groupings were created. On average, each typology group represented around 1,100 dwellings (0.3% of the target stock), ranging from 30 dwellings (< 0.01% of the target stock) to 7,300 dwellings (1.5% of the target stock). Appendix 6 details the full list of typology groupings modelled against the initial combination of typology factors.

Archetype selection from within typology groups

3.24 The archetype chosen to represent each typology group had to be typical, and average with regard to any variation within the groupings.

3.25 As heating type, wall type, age and dwelling type were central to the typology creation, these factors were not important with regard to the choice of archetype within groupings.

3.26 The typology creation, however, only partially took account of size of dwellings and energy efficiency. Therefore, archetypes were chosen by selecting the dwellings with the median annual energy consumption[29] within a typology grouping. This ensured that variations in both size of dwellings and energy rating (within EPC band) were accounted for in the choice of archetypes.

3.27 Note that some archetype groups contained (and were therefore defined by) a single dwelling in the SHCS data. Similarly, a number of archetype groups covered only two cases in the SHCS data. For these groupings, a case was chosen at random to represent the archetype.

3.28 To confirm that the 355 chosen archetypes reflected the target stock, the prevalence of nine characteristics among these were compared with the prevalence in the target stock overall. Table 3.3 shows the results.

3.29 Overall, there was a very good match. As would be expected, there was very little difference with regard to characteristics that formed part of the typology creation. There was also little difference with regard to most characteristics that had not been part of the typology creation. For example, 31% of all dwellings in the target stock had rooms in the roof. In comparison, 32% of the archetypes (weighted to the target stock) had rooms in the roof. The archetypes were also very similar to the target dwellings overall with regard to un-insulated lofts and the proportion of dwellings that lacked mains gas.

Table 3.3: Comparison of prevalence of selection characteristics among all dwellings in the target stock and the modelled archetypes

Characteristic	Among all target dwellings (weighted) (N=1,786)	Among modelled archetypes (weighted to target population)	Archetypes with characteristic (unweighted)
Detached dwelling	45%	45%	157
Sandstone walls	29%	30%	100
Mains gas boiler	40%	40%	96
Pre-1919	46%	47%	153
Rooms in the roof	31%	32%	106
Loft in original dwelling but less than 250mm of insulation	60%	60%	198
No mains gas	51%	51%	219
More than 5 rooms	44%	41%	137
Single glazed	18%	13%	58

[29] Based on SAP 2005 figures

3.30 Single glazing was less common among the archetypes than in the target stock. This means that dwellings with single glazing were under-represented in the outputs of the improvement outputs by about 20,000 (5% of the target stock). Therefore, the modelled outputs may have under-estimated the number of properties where double, secondary or triple glazing would be part of the package of cheapest measures to get these properties up to the various scenario bandings.

3.31 Dwellings with more than 5 rooms were also under-represented. However, because the archetype dwelling was chosen based on the median energy consumption, mid-size dwellings were more likely to be over-represented among the archetypes while very small and very large size dwellings will be likely to be slightly under-represented. Overall, the net effect on the modelled outputs is likely to be minimal.

4 METHODOLOGY FOR MODELLING IMPROVEMENTS

4.1 In this section, we provide an overview on the identification of the potential measures that were selected for improving the energy performance of the 355 archetypes, and the evolution of the hierarchy for determining the basis for selecting which improvements were modelled to meet different SAP energy banding improvement targets. The modelling was completed using a SAP 2012 program, however, the approach used was developed to be consistent with RdSAP conventions so that the results could be replicated using a RdSAP 2012 program.

Improving the energy performance of the 355 selected archetypes

4.2 With the establishment of the typology and the identification of the 355 archetypes, the next stage of the project involved modelling the energy performance of each of the individual archetypes before improvement, identifying and modelling the range of measures to improve their respective energy performance, and evaluating the impact of the various improvements.

4.3 Prior to modelling each of the 355 archetypes, a preliminary analysis of two sample dwellings was carried out with the intention of:

- identifying the energy efficiency improvement measures to be modelled for the dwellings to be improved, both single measurements and packages of improvements;
- assessing the impact of these measures on improving the energy efficiency of the dwellings to be improved;
- evaluating the impact, cost and cost effectiveness of these measures for the dwellings to be improved.

4.4 This analysis was used to inform the basis of establishing a hierarchy for applying upgrades across the poorer energy performing parts of the Scottish dwelling stock. Various approaches to establishing this hierarchy were explored in this analysis, including impact of the improvement on energy ratings, lifetime cost savings, carbon dioxide emission reductions, and returns on investment. These are discussed in more detail below. As an important consideration would be the cost to the public of meeting any standard, the lowest indicative cost of achieving the agreed target standards became the basis of identifying the improvement packages for each archetype. The final decision on the hierarchy to be applied was taken by the REEPS Research Advisory Group (RAG).

Base data

4.5 The base data used in this energy modelling was extracted from the 2010 to 2012 SHCS data sets, for each dwelling. The SHCS has been designed to collect the necessary data to enable its analysis to emulate an RdSAP assessment of each property surveyed since the introduction of Energy

Performance Certificates (EPCs) on the existing dwelling stock in 2009. A sample of the data extract is set out in Appendix 11.

4.6 At the time that this modelling was being carried out (i.e. during the latter half of 2014) it was known that the version of RdSAP being used in the production of EPCs in the UK would be changing from RdSAP 2009 v9.91 to RdSAP 2012 v9.92[30] (see Appendix 6). No approved RdSAP 2012 v9.92 software was available at the time. Rather than carry out the analysis with RdSAP 2009 v9.91 software, and then attempt to convert it to version 9.92 later, it was agreed with the REEPS RAG to carry out the analysis using a full SAP 2012 v9.92 software program[31].

4.7 The use of a full SAP program necessitated additional work to convert the SHCS data set for an archetype into a format that was compatible with the data entry requirements of the SAP program, which are different than those of an RdSAP program[32]. The intention was to keep the SAP assessment as close to the RdSAP assessment as possible. As a cross check of this process, the first cohort of 12 modelled archetypes were also entered into both an approved full SAP 2009 v9.90 program and an approved RdSAP 2009 v9.91[33] program, and the results from the two programs were within 1 SAP point in all 12 cases, which is within the accepted ±4 SAP point error bar applied to the SAP and RdSAP program approval process. Appendix 11 sets out this process in more detail.

Potential improvement measures

4.8 The list of potential improvement measures that were applied to the 355 archetypes was collated from a variety of sources, including:

- the Energy Efficiency Standard for Social Housing (EESSH)
- Appendix T of SAP (that is, the measures that appear within the energy advice report section of the EPC, and the conventions governing their inclusion)

[30] The eventual change took place on December 7th, 2014.
[31] National Energy Services' Plan Assessor v6.1 program was used. This is a fully approved SAP 2012 program.
[32] RdSAP programs use a geometric model to calculate the gross heat loss wall areas, roof areas and floor areas from the floor area, exposed perimeter, and storey height of each storey. Within RdSAP programs are algorithms to calculate window areas and to convert external dimensions to internal dimensions. While RdSAP programs assign U-values to most wall and roof constructions by using look up tables, it calculates the U-values for stone walls and for heat loss floors individually. By comparison, SAP programs require the use of internal dimensions, and the specific areas and U-values for each heat loss wall, roof, and floor in a dwelling. The necessary SAP data entry items were produced by a combination of individual hand calculations (e.g. the wall areas and roof areas), using the RdSAP default U-values, or entering the base data into an RdSAP 2009 v9.91 program to obtain the relevant data entry item (e.g. stone wall U-values, floor U-values, window areas). Where external dimensions were collected in the SHCS data set, these were converted to internal dimensions using the published RdSAP algorithms Some SAP data entry items were assumed using the RdSAP assumptions (e.g. window orientation, the draughtproofing of windows and doors, the hot water cylinder details where no access to the cylinder is available, and party wall construction).
[33] National Energy Services Plan Assessor v5.5.6 SAP program and NES-One RdSAP v9.91 program

- Appendix V of SAP (that is, the measures that are eligible through Green Deal financing)
- measures potentially included within Energy Company Obligation (ECO)
- measures eligible under the Renewable Heat Incentive
- the various strands of the Home Energy Efficiency Programme for Scotland (HEEPS).

4.9 Additionally, account was taken of suggestions from the REEPS RAG, and the measures assessed in another recent report[34]. While there was a lot of overlap between the measures drawn from these various sources, there were also differences. The resultant list of potential 38 improvement measures encompassed insulation, ventilation, heating, hot water, space and water heating controls, renewables, and other energy saving improvement options.

4.10 By being cognisant of the measures included within the Green Deal, Energy Company Obligations and the Renewable Heat Incentive, there is potential that some of the proposed improvement to raise standards within the private sector dwelling stock may attract funding from these various schemes. However, the intention of this report is not to limit its exploration of improving the poorer energy performing dwellings to only those measures where grant funding is currently available, or presume that any grant funding will be available in the future.

4.11 The insulation measures included:

- loft insulation, including top-up loft insulation (M1)
- flat roof insulation (M2)
- room in the roof insulation (M3)
- cavity wall insulation (M4)
- solid wall insulation (M5)
- floor insulation , both beneath suspended timber floor insulation, and insulation on top of solid floors (M6)
- double glazing (M7)
- secondary glazing (M8)
- triple glazing (M9)
- insulated external doors (M10)
- hot water cylinder insulation jackets M11)

4.12 The ventilation measures included:

- draught proofing of windows, doors and loft hatch as necessary (M12)
- fit baffles / dampers to block open chimneys when not in use (M13)

[34] Parity Projects (2014) *Analysis for WWF and UKGBC: achieving minimum EPC standards in housing*, version 1.4, 22 May 2014, Parity Projects, London

4.13 The heating measures included:

- replacement / renewal of an existing gas, oil or LPG central heating boilers with condensing boilers (M14 and M15)
- new gas central heating system (where none before) (M16)
- new oil or LPG central heating system (where none before) (M17)
- biomass central heating system (M18)
- fan-assisted electric storage heaters (M19)
- high heat retention electric storage heaters (also referred to as Quantum storage heaters) (M20)
- direct electric heating appliances on an off-peak tariff (M21)
- electric thermal store (CPSU) wet central heating system (M37)
- air source heat pumps (both air-to-water and air-to-air systems) (M22 and M35)
- ground source heat pumps (M23)
- replacing the secondary heating with a more efficient / appropriate appliance (M36)

4.14 The space and water heating control measures included:

- fitting central heating controls such as room thermostats, programmers, and thermostatic radiator valves either individually, or as a package of controls (M24, M25, M26 and M27)
- fitting a cylinder thermostat on the hot water cylinder (M34)
- switching from manual charge control to automatic charge control for electric storage heating (M28)

4.15 The renewables or low carbon technology measures included:

- solar hot water (M29)
- photovoltaic panels (PVs) (M30)
- wind turbines on the roof top (M31)
- wind turbines on a stand-alone mast (M32)

4.16 The switching of electric storage heaters from a traditional off-peak tariff onto one of the 24-hour tariffs or electric radiator systems to an Economy 10 tariff were included as a measure (M38).

4.17 Switching to 100% low energy lighting within a dwelling was also included (M33).

4.18 Two measures that were considered (i.e. fitting shutters to single glazed windows, and the fitting of radiator panels) were not included in the final modelling as they do not have conventions within SAP or RdSAP on how they should be included within the models, or how their impacts would be modelled.

4.19 Not all of the 38 potential improvements were modelled for every dwelling type. In some instances the dwelling may already have the improvement installed. In others, the improvement may not be applicable (e.g. loft insulation in a ground floor flat or floor insulation in a top floor flat). Some of the measures are mutually exclusive, e.g. various new and replacement heating systems. In some instances, a potential improvement measure was not recommended, usually because it would have reduced the energy performance rating (i.e. the SAP score) of the dwelling. A more complete description of each of the 38 improvements is set out in Appendix 2, including descriptions of when the measures were recommended or not recommended.

4.20 Another issue to note here is that all of the above improvement measures are asset-based, that is, they relate to improving the energy performance of the dwelling as measured by the EPC energy efficiency rating (i.e. the SAP score). There is nothing included here for energy advice, which should be an integral feature of any improvement programme, or better information being made available to householders (for example, fitting smart meters). Again, neither SAP nor RdSAP include protocols for assessing the impact of energy advice.

4.21 Most of these technologies and the techniques for applying or installing these technologies, are well known within the heating and insulation industry, and have been installed in Scotland for many years. However, not all of these measures will be applicable to a particular dwelling, for example, due to its construction, or its location, or its particular circumstances[35]. Improvement packages for listed buildings, and those in conservation areas, may need to deal with specific design issues if they are going to achieve the potential savings reaped elsewhere.

4.22 Whether a package is affordable, is cost effective, or is acceptable locally (because it may change the external façade of a dwelling) are different questions. These issues can be illustrated by the common use of the term 'hard to treat' dwellings with regard to upgrading a dwelling’s wall insulation. The term is (mis)applied commonly to categorise various wall constructions of both traditional and non-traditional constructions, so that the term can apply equally to traditional solid brick and stone wall dwellings, as well as the wide variety of non-traditional metal-frame, timber frame, and concrete-built dwellings[36]. However, most of these wall types are not 'hard to treat' *per se*. For example, wall insulation techniques have been used in Scotland for over

[35] The assumption at this point has to be that if an improvement measure is being installed it is being done appropriately with regard to both the technical requirements of the building, and the procedures for fitting it so as to not to put the building fabric at risk. Research sponsored by Historic Scotland has raised concerns about the appropriateness of the use of, for example, some wall insulation materials within ‘traditional’ buildings (i.e. stone) and problems with interstitial condensation. Appropriate, natural, breathable insulation materials are available on the market. The question is one of appropriate design and installation, not one of technical feasibility.
[36] See Scottish Office Building Directorate (1987) *A Guide to Non Traditional Housing in Scotland,* HMSO, Edinburgh

30 years to improve just these types of dwellings. There may be specific technical issues to ensure the design of the insulation is technically appropriate for specific dwellings or wall constructions, but they can be insulated. The real issue is usually that these dwellings are 'expensive to treat' when compared against the cost of installing cavity wall insulation in a dwelling. Certainly, there may be issues with regards to the aesthetics of changing the external facades of our dwelling stock, but these are social, planning or local issues, not technical issues.

4.23 Again, some of the improvements may be disruptive for the occupants. That was not a consideration in the modelling, but would certainly be a consideration for householders when contemplating improving the energy efficiency of their dwellings.

Establishing a hierarchy of measures

4.24 It would be relatively straightforward to establish a hierarchy of improvements if the impact on energy efficiency or the increase in the SAP energy efficiency rating was the only issue of concern. However, the various measures are very different in terms of their capital costs which are not necessarily reflected by their impact on the improvement in energy efficiency or the SAP rating. Further, other political priorities are also in play. There is an EU obligation to generate 20% of our energy from renewable resources. The government has an obligation to reduce fuel poverty by 2016 by as far as reasonably practicable. The Climate Change (Scotland) Act 2009 sets out the Scottish Government's target to reduce a basket of greenhouse gas emissions by 42% by 2020. Not all of the improvements set out in paragraphs 4.11 - 4.17 above affect fuel bills, greenhouse gas emissions and fuel bills in the same way. Installing a measure may positively impact on one improvement indicator but have a negative consequence on another.

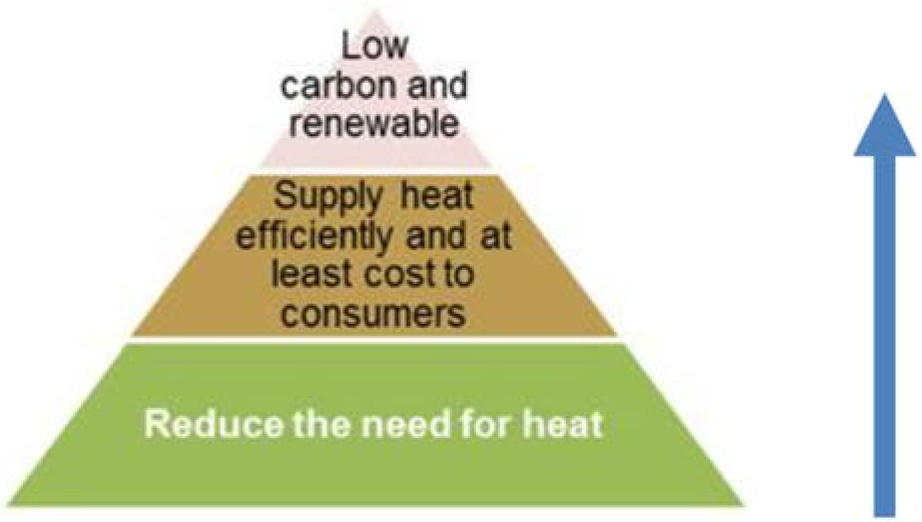
4.25 It is possible to improve the SAP score without reducing CO_{2e} emissions (or even increase them), and conversely, significant reductions in CO_{2e} emissions can be achieved but with a SAP score reduction. For example, in an off-gas grid dwelling with a 90.8% efficient LPG condensing boiler, replacing it with an oil condensing combi boiler of the same efficiency would achieve a higher SAP score (by +19 points) and reduce the household fuel costs according to RdSAP analysis, but will result in increased CO_{2e} emissions (see Table 4.1). Oil is a more polluting fuel within the SAP and RdSAP process than LPG, but a fuel with lower unit fuel costs. By contrast, a biomass boiler is a significantly less polluting fuel. Replacing the LPG boiler with a considerably less efficient wood pellet boiler (using the default RdSAP efficiency of 63%) would significantly reduce CO_{2e} emissions, for about the same fuel costs as the LPG boiler, but achieve a much lower SAP score (by -10 points). The optimal strategy for this dwelling would be dependent upon whether you were prioritising the SAP score, the household fuel costs, or the CO_{2e} emissions.

Table 4.1: Comparing Ratings, Emissions and Fuel Costs by Heating and Fuel

Heating	Boiler efficiency	SAP Energy Efficiency rating	SAP Environmental Impact rating	RdSAP Fuel Costs £/year	RdSAP CO_{2e} emissions tonnes/ year
LPG condensing boiler	90.8%	39	51	£1,549	4.38
Oil condensing boiler	90.8%	58	46	£1,073	4.89
Wood Pellet boiler[37]	63%	29	88	£1,519	1.07

4.26 Adopting the environmental ethos - reduce ' reuse 'renew ' generate - has some merit, and is consistent with the Scottish Government's vision for its recently published heat generation strategy. Its heat hierarchy is illustrated in Figure 4.1 below.

Figure 4.1: Scottish Government's Heat Hierarchy[38]



4.27 Installing insulation before heating has the benefit of reducing a dwelling's energy demand, and therefore avoids unnecessary over-sizing of the heating system, which may contribute to inefficiencies within the system: the less you need, the less you have to supply regardless of the heating system. It has the

[37] This is not intended as a recommendation for low efficiency biomass or wood boilers to be installed. Rather, it is intended to be illustrative of the impact of the trade-offs that occur between fuel prices, carbon conversion coefficients and heating efficiencies within SAP and RdSAP. Much higher efficiency wood pellet and wood log boilers are available in SAP and RdSAP.

[38] Source: The Scottish Government (2014) Towards Decarbonising Heat: Maximising the Opportunities for Scotland, The Scottish Government, Edinburgh, p9 available at http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/Heat/HeatMap

added benefits of reducing pressures on household fuel bills and reducing emissions associated with overall energy use in a dwelling. Reducing household fuel bills is a key factor in combatting fuel poverty in Scotland.

4.28 Reusing components of the existing heating system where appropriate, and the upgrading of existing heating controls to promote more efficient use of the existing system, avoids unnecessary capital costs.

4.29 Replacing inefficient and / or expensive to use heating systems and controls to improve system efficiencies or reduce household fuel costs where this makes economic sense, may be more economic than investing in on-site renewables or investing in national generating capacity. The impetus for the Scottish Government's consultation on a Heat Generation Policy is that investing in group heating where there is a sufficient heat demand will realise improvements in the efficiency of producing heat (compared with those achieved by individual boilers), reduce greenhouse gas emissions and lower fuel costs for households[39].

4.30 Then there is a temporal dimension. Some technologies today may not tick all of the boxes in terms of improving energy efficiency, reducing emissions, and lowering fuel bills. For example, electric heating storage heating may be an issue because of its current poor fuel price comparison with mains gas. The higher associated emissions because of the current electricity generation mix, means it also compares poorly in terms of CO_{2e} emission reductions. Yet, when you couple higher thermal capacity and electric storage heaters with increasing world gas prices, more volatile world gas supply chains, and the increasing decarbonisation of the grid, electricity may become the fuel of choice in the future. Storage heaters also provide at least a partial solution to dealing with the issue of variability in availability associated with some renewable technologies.

4.31 There is no single solution. These issues were explored further by modelling the impact of various improvements on two sample dwellings.

Costing the modelled improvement measures

4.32 The REEPS RAG took the decision to use the Product Characteristics Database File (PCDF) costs for improvement measures that were modelled in the absence of a robust, comprehensive, nationally recognised, evidence based, alternative. RAG was not willing to base the research modelling on prices quoted by a small number of contractors. RAG was also mindful of ensuring research results were consistent with EPC reports, which are based on PCDF costs. In addition, RAG took the decision to use mean PCDF costs, as corresponding unit costs were not available. It was recognised by RAG that this will lead to some over/under estimation of costs for individual archetypes, depending on their size and other characteristics. However, the use of mean

[39] The REEPS RAG took the decision not to include the “connection to community heating” as one of the improvement options because its applicability would be much more limited than the other improvement options. A case study of the potential impact has been prepared and submitted to the Scottish Government REEPS team.

costs would result in the best central estimates for the aggregated results from the research.

4.33 SAP, RdSAP, and Green Deal assessments use the PCDF as the basis of assessing the indicative cost of the improvement measures. For most measures in the PCDF, both an indicative low and a high cost figure are given (see the Low Cost Range A and High Cost Range A columns in Table 4.2 below), though there are some measures with variable costs in the Low Cost B and High Cost B columns[40] (e.g. low energy lighting, storage heaters, and insulated doors, where the number of each present in the dwelling is multiplied by this variable cost to get the total cost of the improvement measure). For this modelling exercise, the REEPS RAG took the decision to use mean PCDF cost of the measure when calculating the cost of the improvements. The calculated mean cost is also set out in Table 4.2

4.34 The PCDF improvement costs do not cover all of the 38 improvements included in this analysis, and were supplemented with costs from other sources where necessary. These supplementary costs and their source are set out in Table 4.2a.

4.35 Alternative costs were investigated as part of this research project (see Appendix 3 of this report), and discussed in the meetings of the REEPS RAG.

Modelling two sample dwellings

4.36 Two of the poorest scoring dwellings in terms of their SAP score within the SHCS data were identified and modelled with a full SAP 2012 program[41]: a detached bungalow and a top floor gable end flat. These dwellings were selected specifically because they rated so poorly on their SAP score – the worst scoring house and the worst scoring flat. One possible improvement target that was discussed with the REEPS RAG was raising the SAP score to at least Band D (that is, a SAP score of 55 or better) across all of the Scottish dwelling stock. If these two sample dwellings could be improved to achieve at least a SAP Band D score then the view was that it should be possible to achieve SAP Band D across all of the stock.

4.37 Both of the sample dwellings would be considered 'hard to treat': the bungalow has solid stone walls, and the top floor flat has a solid brick gable and rear wall and sandstone front wall. Both had no insulation added to the walls, the floors or the roof spaces. The flat did benefit from double-glazing. Heating in both cases was via room heaters: a solid fuel open fire in grate supplemented by electric heaters in the bungalow, and direct acting electric heating in the flat. The bungalow relied on instant electric water heater, while the flat had an electric immersion heater within a poorly insulated hot water

[40] e.g. low energy lighting and insulated doors, where the number of each present in the dwelling is multiplied by this variable cost to get the total cost of the improvement measure Electric storage heaters have a cost range multiplied by the number of storage heaters to be installed.
[41] See Appendix 6 on SAP and RdSAP

cylinder. The bungalow achieved a SAP 2012 score of '1'[42]; the flat scored '5' on the SAP 2012 scale.

4.38 Various improvements were applied to both dwellings, taking account of their prevailing situation and location - so installing floor insulation, a ground source heat pump, and a standalone wind turbine were assessed with the detached bungalow but not with the top floor flat. The detached bungalow was off the gas grid, so various non-gas fuel options were assessed; the flat had a mains gas meter present so mains gas heating was included and the potential improvements assessed.

Table 4.2: Cost of Improvement Measures used in Modelling[43]

Improvement Measure	Low cost range A	Low cost B	High cost range A	High cost B	Mean cost
Loft insulation	100		350		225[44]
Cavity wall insulation	500		1,500		1,000
Hot water cylinder insulation	15		30		22.5
Draught proofing	80		120		100
Low energy lights	0	5			5
Cylinder thermostat	200		400		300
Heating controls for wet central heating system	350		450		400
Heating controls for warm air system	350		450		400
Upgrade boiler, same fuel	2,200		3,000		2,600
Biomass boiler	7,000		13,000		10,000
Biomass room heater with boiler	7,000		13,000		10,000
New or replacement storage heaters	0	300	0	400	350
New or replacement quantum storage heaters					700[45]
Replacement warm-air unit	1,250		2,500		1,875
Solar water heating	4,000		6,000		5,000
Double glazing	3,300		6,500		4,900
Secondary glazing	1,000		1,500		1,250
Solid wall insulation	4,000		14,000		9,000
Solid wall insulation	4,000		14,000		9,000
Condensing oil boiler	3,000		7,000		5,000
Change heating to gas condensing boiler	3,000		7,000		5,000
Photovoltaics	9,000		14,000		11,500
Wind turbine on roof	1,500		4,000		2,750

[42] In fact, it actually scored '-24' within the SAP 2012 calculation, but within SAP methodology all ratings of less than '1' are quoted as 1.
[43] (Sources: the Product Characteristics Database File, www.ncm-pcdb.org.uk/sap)
[44] For loft insulation the mean cost was not used in the modelling. Instead the low range cost (i.e. £100 was used where the loft insulation modelled was a top up of 100mm or less on existing loft insulation; where the amount of loft insulation added was more than 100mm (up to 300mm for a virgin loft, the high range cost (i.e. £350) was used in the modelling
[45] At the time that the modelling was being carried out in the latter part of 2014, the PCDF did not include a cost of the Quantum storage heaters. A cost of £700 was identified by searching the internet.

Improvement Measure	Low cost range A	Low cost B	High cost range A	High cost B	Mean cost
Flat roof insulation	850		1,500		1,175
Roof room insulation	1,500		2,700		2,100
Flue gas heat recovery	900				450
Floor insulation	800		12,00		1,000
Insulated doors	0	500			500
Waste water heat recovery	585		725		655
Biomass boiler	7,000		13,000		10,000
Solid wall insulation	4,500		15,500		10,000
ASHP with radiators	6,000		10,000		8,000
ASHP with underfloor	6,000		10,000		8,000
Micro CHP	5,500				5,500
GSHP with radiators	9,000		17,000		13,000
GSHP with underfloor	9,000		17,000		13,000
Triple glazing	5,000		10,000		7,500
Wind turbine separate mast	15,000		25,000		20,000

Table 4.2a: Supplementary Improvement Measure Costs used in Modelling

Improvement Measure	Unit Cost	source
Fit baffle / damper to open fire	£50	Parity Projects report[46]
New hot water cylinder with 50mm spray foam	£750	Parity Projects report
Electricity Meter change	£200	Discussion with electricity utility
Electric wet system (flow / CPSU / thermal store)	4,000	Parity Projects report
Solid fuel ‘cassette’ insert into open fire	£450	Internet search

Improving the Detached Bungalow

4.39 This detached bungalow has solid stone walls approximately 600mm thick, a pitched roof and suspended timber floors, with no insulation added to the walls, the floors or the roof spaces. Heating is by a solid fuel open fire in one room supplemented by portable electric heaters in other rooms. Hot water is via an instant electric water heater; i.e. no hot water cylinder. The property is single glazed, and the windows and doors are not draught proofed. The only energy saving feature in the property is that all light fittings have low energy lamps. The property is well off the gas grid. The publicly quoted SAP 2012 rating for this property is '1', i.e. a property at the bottom of SAP G banding.

4.40 Table 4.3 sets out the various improvement measures assessed for this dwelling. The improvements comprise a variety of single insulation, ventilation, heating, hot water, and renewable measures, plus combinations of insulation with various heating systems and renewables. This table is rank ordered by their resultant SAP rating after the improvement. Both the reported

[46] Parity Projects (2014) *Analysis for WWF and UKGBC: achieving minimum EPC standards in housing*, version 1.4, 22 May 2014, Parity Projects, London

SAP score and the one actually calculated within the SAP program are shown. The calculated SAP score (i.e.' -24'[47]) was used here as the starting point, otherwise where the increase in the SAP rating was less than 25 points for a particular improvement option in this particular dwelling, the publically reported SAP score of '1' would show no change despite the improvement. In an RdSAP assessment of this dwelling, a number of recommended improvements would show no increase in the SAP score.

4.41 What emerged from this assessment is that no single improvement, regardless of whether it was a heating, insulation or renewable measure, was sufficient on its own to raise this dwelling above SAP Band G. Even when measures were combined, their impact was not always sufficient to improve the SAP banding. It was only with combining both heating and insulation measures that a SAP banding of F (i.e. a SAP score of 21 or better) was achieved. Getting to SAP Band E (i.e. a SAP score of 39 or better) required packages of comprehensive insulation, high performance double glazing, and heating measures. The impact of some of these packages was sufficient to achieve a SAP Band D rating (i.e. a SAP score of 55 or better) in this property.

Table 4.3: Detached Bungalow Improvement Options - Rank ordered by SAP Rating and Estimated Fuel Costs (smallest to largest increase in SAP points)

Improvement Option	**SAP rating**	**SAP EPC Band**	**kg CO_{2e} per year**	**SAP fuel costs £ per year**
Base case – as surveyed	1 [-24]	G	33,091	£3,427
Solar hot water panels ($4m^2$)	1 [-23]	G	32,711	£3,387
Fit baffle / damper on open fire (damper)	1 [-23]	G	32,589	£3,377
Insulated doors (2 doors)	1 [-23]	G	32,429	£3,361
Draught proof windows and doors (DP)	1 [-22]	G	32,237	£3,341
Damper + DP	1 [-22]	G	31,756	£3,293
Wind turbine on roof (2m diameter)	1 [-22]	G	32,737	£3,337
Photovoltaics (2 kWp) (PVs)	1 [-21]	G	32,374	£3,245
Floor insulation (U-value 0.25) (FI)	1 [-20]	G	30,946	£3,212
Low-E Double Glazing (U-value 2.1) (DG)	1 [-20]	G	30,836	£3,201
Low-E + Argon filled Double Glazing (U-value 1.8) (DGA)	1 [-20]	G	30,775	£3,195
Electric wet central heating (flow boiler) on E10 tariff + new hot water cylinder (HWC)	1 [-12]	G	14,643	£2,762
Electric wet central heating (flow boiler)on E10 tariff + new HWC + damper	1 [-11]	G	12,825	£2,716
Wind turbine on stand-alone mast (5m diameter)	1 [-11]	G	30,192	£2,690
Loft insulation (U-value 0.13) (LI)	1 [-10]	G	25,468	£2,662
LI + DP	1 [-9]	G	24,600	£2,575

[47] As already noted, within the SAP methodology SAP scores calculated to be less than ‘1’ are quoted on the EPC as a SAP score of ‘1’. Where the publically quoted SAP score is 1, the calculated SAP score can be found on the SAP worksheet. In all other cases, where the SAP score is 1 or higher, the rating on the SAP worksheet and that on the EPC will be the same (rounded to the nearest integer).

Improvement Option	SAP rating	SAP EPC Band	kg CO_{2e} per year	SAP fuel costs £ per year
Electric room heater system on E10 tariff + new HWC	1 [-8]	G	14,940	£2,542
Solid Wall insulation (U-value 0.3) (SWI)	1 [-8]	G	24,177	£2,533
Electric room heater system on E10 tariff + new HWC+ damper	1 [-7]	G	11,785	£2,493
LI + DP + FI	1 [-4]	G	22,409	£2,355
Solid Fuel (SF) range boiler 67.5% + new HWC	2	G	18,813	£2,107
Air Source Heat Pump (ASHP) + radiators + new HWC	3	G	8,158	£2,073
Electric wet central heating - CPSU on E18 tariff	4	G	14,787	£2,030
Electric fan storage heating (auto charge control) + panel heaters + new HWC + damper	6	G	14,890	£1,964
Electric wet central heating CPSU + damper	7	G	13,013	£1,915
Electric fan storage heating (auto charge control) + new HWC	7	G	17,308	£1,914
Ground Source Heat Pump + new HWC	12	G	6,826	£1,735
Oil condensing combi 90.1%	13	G	10,608	£1,690
Electric Wet thermal store on E18 off peak tariff	14	G	15,678	£1,671
Oil condensing range 90% + new HWC	14	G	10,503	£1,670
LI + DP + SWI	14	G	15,528	£1,665
Wood log boiler 80% + new HWC	16	G	3,769	£1,606
Quantum storage heaters + new HWC	17	G	14,492	£1,566
Electric fan storage heating (auto charge control) + new HWC + LI	19	G	13,428	£1,514
Electric Wet thermal store on E18 off peak tariff + damper	20	G	13,743	£1,504
Electric fan storage heating (auto charge control) + new HWC + LI + DP	21	F	12,987	£1,468
Insulation package (LI + SWI + FI + DP)	22	F	13,339	£1,445
Oil condensing combi 90.1% + LI	25	F	8,469	£1,365
Oil condensing combi 90.1% + LI + DP	26	F	8,223	£1,327
Insulation package + DGA	28	F	11,628	£1,273
Quantum storage heaters + new HWC + LI	29	F	11,487	£1,256
Oil condensing combi 90.1% + LI + DGA + DP	29	F	7,759	£1,254
Insulation package + DGA + Solar hot water	30	F	11,221	£1,230
Quantum storage heaters + new HWC + LI + DP	31	F	11,143	£1,220
Electric Wet (thermal store) + damper + LI	32	F	10,792	£1,192
Insulation package + DGA + Wind turbine on roof (2m diameter)	32	F	11,274	£1,183
Electric Wet (thermal store) + damper + LI + DP	33	F	10,463	£1,157
Oil condensing combi 90.1% + LI + DGA + DP + FI	34	F	7,120	£1,155
Quantum storage heaters + new HWC + LI + DGA + DP	34	F	10,502	£1,154
Insulation package + DGA + PVs	36	F	10,911	£1,091
Electric Wet (thermal store) + damper + LI + DGA + DP	37	F	9,806	£1,087
Electric Wet (thermal store) + damper + LI + DP + FI	38	F	9,604	£1,066
Quantum storage heaters + new HWC + LI + DGA + DP + FI	38	F	9,616	£1,062
Electric Wet (thermal store) + damper + LI + DGA + DP + FI	41	E	8,936	£995
Insulation package + DGA + ASHP + new HWC	48	E	3,478	£884
Insulation package + DGA + Electric Storage Heating + new HWC	50	E	6,238	£843
Insulation package + DGA + SF range 67.5% + new HWC	51	E	7,378	£829

Improvement Option	SAP rating	SAP EPC Band	kg CO_{2e} per year	SAP fuel costs £ per year
Insulation package + DGA + Electric Storage Heating + electric panel heaters + new HWC	53	E	5,606	£800
Insulation package + DGA + Ground Source Heat Pump	55	D	3,006	£764
Insulation package + DGA + oil condensing combi 90.1%	55	D	4,781	£762
Insulation package + DGA + oil condensing range 90% + new HWC	58	D	4,524	£714
Insulation package + Electric Wet (thermal store) + damper	59	D	6,004	£684
Insulation package + DGA + wood log boiler 80% + new HWC	60	D	2,398	£676
Insulation package + DGA + Quantum storage heaters + new HWC	60	D	5,842	£673
Insulation package + DGA + Electric Wet (thermal store) + damper	64	D	5,308	£611
Insulation package + DGA + Wind turbine on mast (5m diameter)	68	D	8,729	£537

4.42 In Table 4.4 the indicative capital cost of the improvement options are set alongside impact of the various measures in terms of the changes in the SAP scores, the reduction in CO_{2e} emissions, and the reduction in fuel bills. The last three columns of Table 4.4 set out the respective relative cost of a single point increase in the SAP rating, the cost of reducing CO_{2e} emissions by 1 kg per year, and the payback period of the assessed measures. These relative costs vary considerably.

4.43 What emerges from Table 4.4 is that the capital cost of the improvements are not correlated with their respective impacts on the SAP ratings, the reduction in CO_{2e} emissions, or fall in fuel costs[48].

Table 4.4: Impact and Cost of Improvements - Detached Bungalow

Improvement Option	Capital cost £	increase in sap points	CO_{2e} emissions saving (kg CO_{2e} / year)	Fuel bill saving (£/year)	Cost / SAP point increase (£)	Cost / kg CO_{2e} per year saved (£)	payback (years)
Solar hot water panels (4m^2)	£5,000	1	380	£40	£4,250	£11.18	106.3
Fit baffle / damper on open fire (damper)	£50	1	502	£50	£50	£0.10	1.0
Insulated doors (2 doors)	£1,000	1	662	£66	£1,400	£2.12	21.2
Draught proof windows and doors (DP)	£100	2	854	£86	£96	£0.23	2.2
Damper + DP	£150	2	1335	£134	£121	£0.18	1.8
Wind turbine on roof (2m diameter)	£2,750	2	354	£90	£1,375	£7.77	30.6
Photovoltaics (2 kWp) (PVs)	£11,500	3	717	£182	£2,467	£10.32	40.7
Floor insulation (U-value 0.25) (FI)	£1,000	4	2145	£215	£209	£0.39	3.9
Low-E Double Glazing (U-value 2.1) (DG)	£4,900	4	2255	£226	£1,225	£2.17	21.7
Low-E + Argon filled Double Glazing (U-value 1.8) (DGA)	£4,900	4	2316	£232	£1,225	£2.12	21.1
Electric wet central heating (flow boiler) on E10 tariff + new hot water cylinder (HWC)	£4,000	12	18448	£665	£333.3	£0.22	6.0

48 The fuel prices used in calculating the fuel costs for the base case and all of the subsequent improvements were those published in Table 12 of the SAP 2012 manual (see Appendix 8).

Improvement Option	Capital cost £	increase in sap points	CO_{2e} emissions saving (kg CO_{2e} / year)	Fuel bill saving (£/year)	Cost / SAP point increase (£)	Cost / kg CO_{2e} per year saved (£)	payback (years)
Electric wet central heating (flow boiler)on E10 tariff + new HWC + damper	£4,050	13	20,266	£711	£311.5	£0.20	5.7
Wind turbine on stand-alone mast (5m diameter)	£20,000	13	2,899	£737	£1538.5	£6.90	27.1
Loft insulation (U-value 0.13) (LI)	£350	14	7,623	£765	£27.4	£0.05	0.5
LI + DP	£450	15	8,491	£852	£38.3	£0.07	0.7
Electric room heater system on E10 tariff+ new HWC	£2,150	16	18,151	£885	£134.4	£0.12	2.4
Solid Wall insulation (U-value 0.3) (SWI)	£9,000	16	8,914	£894	£752.9	£1.35	13.5
Electric room heater system on E10 tariff + new HWC + damper	£2,200	17	21,306	£934	£129.4	£0.10	2.4
LI + DP + FI	£1,450	20	10,682	£1,072	£70.6	£0.13	1.3
Solid Fuel (SF) range boiler 67.5% + new HWC	£8,500	26	14,278	£1,320	£355.8	£0.65	7.0
Air Source Heat Pump (ASHP) + radiators + new HWC	£8,000	27	24,933	£1,354	£314.8	£0.34	6.3
Electric wet central heating - CPSU on E18 tariff	£4,000	28	18,304	£1,397	£142.9	£0.22	2.9
Electric fan storage heating (auto charge control) + panel heaters + new HWC + damper	£2,500	30	18,201	£1,463	£80	£0.13	1.6
Electric wet central heating CPSU + damper	£4,050	31	20,078	£1,512	£130.6	£0.20	2.7
Electric fan storage heating (auto charge control) + new HWC	£2,150	31	15,783	£1,513	£69.4	£0.14	1.4
Ground Source Heat Pump + new HWC	£13,000	36	26,265	£1,692	£354.2	£0.49	7.5
Oil condensing combi 90.1%	£5,000	37	22,483	£1,737	£145.9	£0.24	3.1
Electric Wet - water storage boiler (thermal store) on off peak tariff	£4,000	38	17,413	£1,756	£105.3	£0.23	2.3
Oil condensing range 90% + new HWC	£5,750	38	22,588	£1,757	£161.8	£0.27	3.5
LI+ DP + SWI	£9,450	38	17,563	£1,762	£341.6	£0.74	7.4
Wood log boiler 80% + new HWC	£8,750	40	29,322	£1,821	£231.3	£0.32	5.1
Quantum storage heaters + new HWC	£3,550	41	18,599	£1,861	£86.6	£0.19	1.9
Electric fan storage heating (auto charge control) + new HWC + LI	£2,500	43	19,663	£1,913	£58.9	£0.13	1.3
Electric Wet - water storage boiler (thermal store) on off peak tariff + damper	£4,050	44	19,348	£1,923	£92.0	£0.21	2.1
Electric fan storage heating (auto charge control) + new HWC + LI + DP	£2,600	45	20,104	£1,959	£60.6	£0.14	1.4
Insulation package (LI + SWI + FI + DP)	£10,450	46	19,752	£1,982	£292.6	£0.68	6.8
Oil condensing combi 90.1% + LI	£5,350	49	24,622	£2,062	£118	£0.24	2.8
Oil condensing combi 90.1% + LI + DP	£5,450	50	24,868	£2,100	£119.5	£0.24	2.8
Insulation package + DGA	£15,100	52	21,463	£2,154	£347.5	£0.84	8.4
Quantum storage heaters + new HWC + LI	£3,900	53	21,604	£2,171	£74.2	£0.18	1.8
Oil condensing combi 90.1% + LI + DGA + DP	£10,050	53	25,332	£2,173	£198.8	£0.42	4.8
Insulation package + DGA + Solar hot water	£20,100	54	21,870	£2,197	£412.4	£1.02	10.1
Quantum storage heaters + new HWC + LI +	£4,000	55	21,948	£2,207	£75	£0.19	1.9

Improvement Option	**Capital cost £**	**increase in sap points**	**CO_{2e} emissions saving (kg CO_{2e} / year)**	**Fuel bill saving (£/year)**	**Cost / SAP point increase (£)**	**Cost / kg CO_{2e} per year saved (£)**	**payback (years)**
DP							
Electric Wet (thermal store) + damper + LI	£4,400	56	22,299	£2,235	£79.2	£0.20	2.0
Insulation package + DGA + Wind turbine on roof (2m diameter)	£17,850	56	21,817	£2,244	£370.8	£0.95	9.3
Electric Wet (thermal store) + damper + LI + DP	£4,450	57	22,628	£2,270	£82	£0.21	2.1
Oil condensing combi 90.1% + LI + DGA + DP + FI	£10,100	58	25,971	£2,272	£172.8	£0.39	4.4
Quantum storage heaters + damper+ new HWC + LI + DGA + DP	£8,650	58	22,589	£2,273	£126.5	£0.33	3.2
Insulation package + DGA + PVs	£26,600	60	22,180	£2,336	£416.1	£1.13	10.7
Electric Wet (thermal store) + damper + LI + DGA + DP	£9,150	61	23,285	£2,340	£152.2	£0.40	4.0
Electric Wet (thermal store) + damper + LI + DP + FI	£5,450	62	23,487	£2,361	£88.9	£0.24	2.3
Quantum storage heaters + solid fuel open fire + new HWC + LI + DGA + DP + FI	£9,650	62	23,475	£2,365	£153.6	£0.41	4.0
Electric Wet (thermal store) + damper + LI + DGA + DP + FI	£10,150	65	24,155	£2,432	£154.2	£0.42	4.1
Insulation package + DGA + ASHP + new HWC	£23,850	72	29,613	£2,543	£362	£0.88	10.3
Insulation package + DGA + Electric Storage Heating + solid fuel open fire + new HWC	£17,250	74	26,853	£2,584	£272.5	£0.75	7.8
Insulation package + DGA + SF range 67.5% + new HWC	£24,350	75	25,713	£2,598	£363.6	£1.06	10.5
Insulation package + DGA + Electric Storage Heating + electric panel heaters + new HWC	£17,650	77	27,485	£2,627	£265.2	£0.74	7.8
Insulation package + DGA + Ground Source Heat Pump	£28,100	79	30,085	£2,663	£389.5	£1.02	11.6
Insulation package + DGA + oil condensing combi 90.1%	£20,100	79	28,310	£2,665	£296.4	£0.83	8.8
Insulation package + DGA + oil condensing range 90% + new HWC	£20,850	82	28,567	£2,713	£294.7	£0.85	8.9
Insulation Package + Electric Wet (thermal store) + damper	£19,150	83	27,087	£2,743	£210.9	£0.65	6.4
Insulation package + DGA + wood log boiler 80% + new HWC	£25,550	84	30,693	£2,751	£317.1	£0.87	9.7
Insulation Package + DGA + Quantum storage heaters + new HWC	£18,650	84	27,249	£2,754	£256.8	£0.79	7.8
Insulation Package + DGA + Electric Wet (thermal store) + damper	£19,150	88	27,783	£2,816	£250.8	£0.79	7.8
Insulation package + DGA + Wind turbine on mast (5m diameter)	£35,100	92	24,362	£2,890	£413.2	£1.56	13.2

4.44 For example, loft insulation and draught proofing, despite their low capital cost, show a bigger impact on the SAP score of this dwelling than some of the more expensive options assessed. While solar hot water is considerably more expensive than either of these two improvement measures, it has very little impact on the SAP rating, and certainly less of an impact than insulating the loft and draught proofing the windows and doors in this property.

4.45 The rank ordering of the improvement options will vary depending on whether they are organised by their indicative capital cost, their impact on the SAP score, their impact on CO_{2e} emissions, or their impact on fuel bills.

4.46 From the examination of the rank ordering of the improvements, the outcomes (e.g. achieving a given SAP score, reducing CO_{2e} emissions, or reducing household fuel costs) cannot be predicted simply from the capital cost of the improvement.

4.47 The last column of Table 4.4 sets out the payback period for the improvements in this dwelling, based on the indicative capital cost of the improvement divided by the estimated annual fuel bill saving. For this dwelling, the improvement payback periods ranged between 0.5 years for loft insulation to over 106 years for the solar panel hot water system.

4.48 An alternative assessment of cost effectiveness examined the financial return on the investments over the lifetime of the respective measures. Using the lifetimes and associated 'in-use factors' of various energy efficiency improvements within the Energy Company Obligation (ECO): Measures Table v1.5[49], the annual fuel bill reduction for each measure was first multiplied by the lifetime of the measure, and then by the in-use factor to effectively discount some of the savings. While individual measures have different lifetimes and different in-use factors, calculating the net lifetime fuel bill reductions is straightforward. It is not straightforward for packages when measures included in the package have different lifetimes and in-use factors. For packages, the additional reductions attributed to each measure were calculated separately[50] and then aggregated (see Table 4.5).

4.49 The net in-use lifetime cost savings of the assessed measures ranged between -£0.84 for every £1 invested (for the solar thermal hot water system) and £58.67 for loft insulation. Several negative values appear in the last column of this table (highlighted in orange): even over the assessed life time of these measures, they do not pay for themselves in terms of financial savings on the estimated fuel cost savings. By contrast, loft insulation here would return £58.67 for every pound invested in installing the measure.

[49] available at https://www.ofgem.gov.uk/ofgem-publications/83100/copyofecomeasurestable-mar2014url.pdf

[50] For example, where loft insulation, draught proofing and a new heating system were assessed, the saving for the loft insulation was multiplied by 42 years, then discounted by 35%; the additional saving attributed to the draught proofing was calculated and then multiplied by a lifetime of 10 years and discounted by 15%; the remaining saving calculated and attributed to the new heating system, and then multiplied by the heating systems lifetime (e.g. 12 years for a boiler and 20 years for electric storage heating) and the in-use factor applied (which is 0 for heating systems).

Table 4.5: Net In-use Lifetime Fuel Cost Saving - Detached Bungalow (rank ordered by smallest to largest cost saving)

Improvement Option	SAP rating	Capital cost £	SAP fuel costs £ per year	Saving £ / year	Lifetime	In-use factor	Net in-use lifetime cost saving per £ cost
Solar hot water panels ($4m^2$)	-23	£5000	£3387	£40	20	0	-£0.84
Wind turbine on roof (2m diameter)	-22	£2750	£3337	£90	10	0	-£0.67
Wind turbine on stand-alone mast (5m diameter)	-11	£20000	£2690	£737	10	0	-£0.63
Photovoltaics (2 kWp) (PVs)	-21	£11500	£3245	£182	25	0	-£0.60
Low-E Double Glazing (U-value 2.1) (DG)	-20	£4900	£3201	£226	20	0.15	-£0.08
Low-E + Argon filled Double Glazing (U-value 1.8)	-20	4900	£3195	£232	20	0.15	-£0.05
Insulated doors (2 doors)	-23	£1000	£3361	£66	20	0.15	£0.12
Solid Fuel (SF) range boiler 67.5% + new HWC	2	£8500	£2107	£1320	12	0	£0.86
Electric wet central heating (flow boiler) on E10 tariff + new hot water cylinder (HWC)	-12	£4000	£2762	£665	12	0	£1.00
Electric wet central heating (flow boiler) on E10 tariff + new HWC + damper	-11	£4050	£2716	£711	12	0	£1.11
Insulation package + DGA + PVs	36	£26600	£1091	£2336	combined	combined	£1.31
Insulation package + DGA + Ground Source Heat Pump	55	£28100	£764	£2663	combined	combined	£1.52
Air Source Heat Pump (ASHP) + radiators + new HWC	3	£8000	£2073	£1354	15	0	£1.54
Insulation package + DGA + SF range 67.5% + new HWC	51	£24350	£829	£2598	combined	combined	£1.56
Ground Source Heat Pump + new HWC	12	£13000	£1735	£1692	20	0	£1.60
Insulation package + DGA + ASHP + new HWC	48	£23850	£884	£2543	combined	combined	£1.63
Solid Wall insulation (U-value 0.3) (SWI)	-8	£9000	£2533	£894	36	0.25	£1.68
Insulation package + DGA + wood log boiler 80% + new HWC	60	£25550	£676	£2751	combined	combined	£1.70
Insulation package + DGA + Solar hot water	30	£20100	£1230	£2197	combined	combined	£1.88
Insulation package + DGA + oil condensing range 90% + new HWC	58	£20850	£714	£2713	combined	combined	£2.05
Insulation Package + DGA + Quantum storage heaters + new HWC	60	£18650	£673	£2754	combined	combined	£2.13
Insulation package + DGA + oil condensing combi 90.1%	55	£20100	£762	£2665	combined	combined	£2.14
Insulation package + DGA + Wind turbine on roof (2m diameter)	32	£17850	£1183	£2244	combined	combined	£2.24
Insulation Package + Electric Wet (thermal store) + damper	59	£19150	£684	£2743	combined	combined	£2.30
Insulation Package + DGA + Electric Wet (thermal store) + damper	64	£19150	£611	£2816	combined	combined	£2.39
Insulation package + DGA + Wind turbine on mast (5m diameter)	68	£35100	£537	£2890	combined	combined	£2.59
Oil condensing range 90% + new HWC	14	£5750	£1670	£1757	12	0	£2.67
Insulation package + DGA + Electric Storage Heating + electric panel heaters + new HWC	53	£17650	£800	£2627	combined	combined	£2.76
Oil condensing combi 90.1% + LI + DGA + DP	29	£10050	£1254	£2173	combined	combined	£2.77
Insulation package + DGA + Electric Storage Heating + new HWC	50	£17250	£843	£2584	combined	combined	£2.80
Insulation package + DGA	28	£15100	£1273	£2154	combined	combined	£3.08
Oil conden combi 90.1% + LI + DGA + DP + FI	34	£10100	£1155	£2272	combined	combined	£3.10

Improvement Option	SAP rating	Capital cost £	SAP fuel costs £ per year	Saving £ / year	Lifetime	In-use factor	Net in-use lifetime cost saving per £ cost
Wood log boiler 80% + new HWC	16	£8750	£1606	£1821	20	0	£3.16
Oil condensing combi 90.1%	13	£5000	£1690	£1737	12	0	£3.17
Electric wet central heating - CPSU on E18 tariff	4	£4000	£2030	£1397	12	0	£3.19
Electric Wet (thermal store) + damper + LI + DGA + DP + FI	41	£10150	£995	£2432	combined	combined	£3.25
Elect Wet (therm store) + damper + LI +DGA+DP	37	£9150	£1087	£2340	combined	combined	£3.35
Electric wet central heating CPSU + damper	7	£4050	£1915	£1512	12	0	£3.48
LI+ DP + SWI	14	£9450	£1665	£1762	combined	combined	£3.89
Quantum storage heaters + new HWC + LI + DGA + DP + FI	38	£9650	£1062	£2365	combined	combined	£3.95
Quantum storage heaters + damper+ new HWC + LI + DGA + DP	34	£8650	£1154	£2273	combined	combined	£4.14
Electric Wet - water storage boiler (thermal store) on off peak tariff	14	£4000	£1671	£1756	12	0	£4.27
Electric Wet - water storage boiler (thermal store) on off peak tariff + damper	20	£4050	£1504	£1923	12	0	£4.70
Insulation package (LI + SWI + FI + DP)	22	£10450	£1445	£1982	combined	combined	£4.79
Oil condensing combi 90.1% + LI + DP	26	£5450	£1327	£2100	combined	combined	£5.72
Oil condensing combi 90.1% + LI	25	£5350	£1365	£2062	combined	combined	£5.81
Draught proof windows and doors (DP)	-22	£100	£3341	£86	10	0.15	£6.31
Floor insulation (U-value 0.25) (FI)	-20	£1000	£3212	£215	42	0.15	£6.68
Elec Wet (thermal store) + damper + LI + DP + FI	38	£5450	£1066	£2361	combined	combined	£6.69
Elec room heater system on E10 tariff+ new HWC	-8	£2150	£2542	£885	20	0	£7.23
Quantum storage heaters + new HWC	17	£3550	£1566	£1861	20	0.2	£7.39
Electric room heater system on E10 tariff + new HWC + damper	-7	£2200	£2493	£934	20	0	£7.49
Electric Wet (thermal store) + damper + LI + DP	33	£4450	£1157	£2270	combined	combined	£7.68
Electric Wet (thermal store) + damper + LI	32	£4400	£1192	£2235	combined	combined	£7.76
Quantum storage heaters + new HWC + LI + DP	31	£4000	£1220	£2207	combined	combined	£9.92
Quantum storage heaters + new HWC + LI	29	£3900	£1256	£2171	combined	combined	£10.12
Electric fan storage heating (auto charge control) + new HWC + LI	19	£2500	£1514	£1913	combined	combined	£10.55
Electric fan storage heating (auto charge control) + panel heaters + new HWC + damper	6	£2500	£1964	£1463	20	0	£10.70
Electric fan storage heating (auto charge control) + solid fuel open fire + new HWC + LI + DP	21	£2600	£1468	£1959	combined	Combined	£10.75
Electric fan storage heating (auto charge control) + new HWC	7	£2150	£1914	£1513	20	0	£13.07
Damper + DP	-22	£150	£3293	£134	combined	combined	£15.66
LI + DP + FI	-4	£1450	£2355	£1072	combined	combined	£19.33
Fit baffle / damper on open fire (damper)	-23	£50	£3377	£50	42	0.15	£34.70
LI + DP	-9	£450	£2575	£852	combined	combined	£47.05
Loft insulation (U-value 0.13) (LI)	-10	£350	£2662	£765	42	0.35	£58.67

4.50 What emerges from Table 4.5 is that all of the renewable technologies perform badly on the return on the cost of their investment i.e. the net in-use lifetime cost savings are all negative despite their potential not being reduced by an in-use factor (i.e. the in-use factor is 0 for these measures). Double glazing also performs badly on this criterion. None of these measures would improve the publically quoted SAP score (i.e. the resultant SAP score is still a negative number so would be rounded to 1 on the EPC). However, even the improvements displaying the best returns on the cost of the investment for this dwelling (i.e. the five best packages all have a net lifetime return of over £15 for each £ invested) are associated with improvements that would not shift the publically quoted SAP score of the dwelling from '1', and their returns would be even higher without the application of the in-use factor.

4.51 To increase the SAP banding of this dwelling, will involve packages of improvement measures with a high return on the investment, and higher cost measures with a lower return. It is possible to achieve a SAP Band D score (i.e. SAP score 55 or better) for an indicative capital cost of between £18,650 and £35,100, with a positive net lifetime return on the investment of between £1.52 and £2.59 per £ invested.

4.52 A similar analysis was performed to assess the calculated lifetime CO_{2e} emissions reductions associated with the different improvement options assessed. Again, using the ECO lifetimes and 'in-use factors' associated with various energy efficiency improvements the annual CO_{2e} reduction for each measure was first multiplied by the lifetime of the measure, and then by the in-use factor applied to effectively discount some of the savings. For packages, the additional reductions attributed to each measure were calculated separately and then aggregated. The net lifetime CO_{2e} emission reductions are set out in the second last column of Table 4.6. By dividing the capital cost of the improvement by the tonnes of CO_{2e} reduction for each assessed measure and package, the respective cost per tonne of carbon saved can be calculated (see the last column of Table 4.6). These costs range from £1.68 for loft insulation up to £776.84 for a stand-alone wind turbine for this dwelling.

4.53 By way of comparison, the traded price for a tCO_{2e} is approximately £3.60 per tonne of CO_{2e}; non-traded price of carbon is approximately £60 per tonne of CO_{2e}. Reductions in energy consumption, and therefore the associated CO_{2e} emissions, in this dwelling would fall in both the traded and non-traded sectors: reductions in electricity consumption are attributable to the traded sector, while gas and other fuels are attributable to the non-traded sector[51].

Table 4.6: Net In-use Lifetime Cost per tonne of CO_{2e} saved - Detached Bungalow (rank ordered by smallest to largest cost per tonne)

Improvement Option	increase in sap	capital cost £	emissions kg CO2 per year	lifetime	in-use factor	net in-use lifetime kg CO2 saved	£ per net lifetime tonne CO2 saved
Loft insulation (U-value 0.13) (LI)	14	£350	25,468	42	0.35	208,108	1.68

[51] DECC (2013) *Valuation of energy use and greenhouse gas (GHG) emissions,* DECC, London

Improvement Option	increase in sap	capital cost £	emissions kg CO2 per year	lifetime	in-use factor	net in-use lifetime kg CO2 saved	£ per net lifetime tonne CO2 saved
LI + DP	15	£450	24,600	combined	combined	215,486	2.09
Fit baffle / damper on open fire (damper)	1	£50	32,589	42	0.15	17,921	2.79
LI + DP + FI	20	£1,450	22,409	combined	combined	293,705	4.94
Electric room heater system on E10 tariff + new HWC + damper	17	£2,200	11,785	20	0	426,120	£5.16
Electric room heater system on E10 tariff+ new HWC	16	£2,150	14,940	20	0	363,020	£5.92
Damper + DP	2	£150	31,756	combined	combined	25,002	£6.00
Electric fan storage heating (auto charge control) + new HWC	31	£2,150	17,308	20	0	315,660	£6.81
Electric fan storage heating (auto charge control) + panel heaters + new HWC + damper	30	£2,500	14,890	20	0	364,020	£6.87
Electric fan storage heating (auto charge control) + solid fuel open fire + new HWC + LI + DP	45	£2,600	12,987	combined	combined	301,906	£8.61
Electric fan storage heating (auto charge control) + new HWC + LI	43	£2,500	13,428	combined	combined	285,708	£8.75
Quantum storage heaters + new HWC + LI	53	£3,900	11,487	combined	combined	431,804	£9.03
Quantum storage heaters + new HWC + LI + DP	55	£4,000	11,143	combined	combined	434,728	£9.20
Electric Wet (thermal store) + damper + LI	56	£4,400	10,792	combined	combined	384,220	£11.45
Electric Wet (thermal store) + damper + LI + DP	57	£4,450	10,463	combined	combined	385,130	£11.55
Quantum storage heaters + new HWC	41	£3,550	14,492	20	0.2	297,584	£11.93
Oil condensing combi 90.1% + LI	49	£5,350	8,469	combined	combined	412,096	£12.98
Floor insulation (U-value 0.25) (FI)	4	£1,000	30,946	42	0.15	76,576	£13.06
Electric Wet (thermal store) + damper + LI + DP + FI	62	£5,450	9,604	combined	combined	415,796	£13.11
Oil condensing combi 90.1% + LI + DP	50	£5,450	8,223	combined	combined	412,010	£13.23
Draughtproof windows and doors (DP)	2	£100	32,237	10	0.15	7,259	£13.78
Wood log boiler 80% + new HWC	40	£8,750	3,769	20	0	586,440	£14.92
Electric wet central heating (flow boiler) on E10 tariff + new HWC + damper	13	£4,050	12,825	12	0	243,192	£16.65
Electric wet central heating CPSU + damper	31	£4,050	13,013	12	0	240,936	£16.81
Electric Wet - water storage boiler (thermal store) on off peak tariff + damper	44	£4,050	13,743	12	0	232,176	£17.44
Electric wet central heating (flow boiler) on E10 tariff + new hot water cylinder (HWC)	12	£4,000	14,643	12	0	221,376	£18.07
Electric wet central heating - CPSU on E18 tariff	28	£4,000	14,787	12	0	219,648	£18.21
Oil condensing combi 90.1%	37	£5,000	10,608	12	0	269,796	£18.53
Insulation package (LI + SWI + FI + DP)	46	£10,450	13,339	combined	combined	556,282	£18.79
Electric Wet - water storage boiler (thermal store) on off peak tariff	38	£4,000	15,678	12	0	208,956	£19.14
Quantum storage heaters + damper+ new HWC + LI + DGA + DP	58	£8,650	10,502	combined	combined	444,511	£19.46
Quantum storage heaters + new HWC + LI + DGA + DP + FI	62	£9,650	9,616	combined	combined	476,142	£20.27
LI+ DP + SWI	38	£9,450	15,528	combined	combined	460,430	£20.52
Oil condensing range 90% + new HWC	38	£5,750	10,503	12	0	271,056	£21.21
Air Source Heat Pump (ASHP) + radiators + new HWC	27	£8,000	8,158	15	0	373,995	£21.39
Oil condensing combi 90.1% + LI + DGA + DP + FI	58	£10,100	7,120	combined	combined	442,710	£22.81

Improvement Option	increase in sap	capital cost £	emissions kg CO2 per year	lifetime	in-use factor	net in-use lifetime kg CO2 saved	£ per net lifetime tonne CO2 saved
Electric Wet (thermal store) + damper + LI + DGA + DP	61	£9,150	9,806	combined	combined	396,299	£23.09
Electric Wet (thermal store) + damper + LI + DGA + DP + FI	65	£10,150	8,936	combined	combined	427,358	£23.75
Oil condensing combi 90.1% + LI + DGA + DP	53	£10,050	7,759	combined	combined	419,898	£23.93
Ground Source Heat Pump + new HWC	36	£13,000	6,826	20	0	525,300	£24.75
Insulation package + DGA + Electric Storage Heating + new HWC	74	£17,250	6,238	combined	combined	693,169	£24.89
Insulation package + DGA + Electric Storage Heating + electric panel heaters + new HWC	77	£17,650	5,606	combined	combined	705,809	£25.01
Insulation package + DGA	52	£15,100	11,628	combined	combined	585,369	£25.80
Insulation Package + DGA + Electric Wet (thermal store) + damper	88	£19,150	5,308	combined	combined	661,209	£28.96
Insulation Package + Electric Wet (thermal store) + damper	83	£19,150	6,004	combined	combined	644,302	£29.72
Insulation package + DGA + oil condensing combi 90.1%	79	£20,100	4,781	combined	combined	667,533	£30.11
Insulation package + DGA + Wind turbine on roof (2m diameter)	56	£17,850	11,274	combined	combined	588,909	£30.31
Insulation package + DGA + oil condensing range 90% + new HWC	82	£20,850	4,524	combined	combined	670,617	£31.09
Insulation Package + DGA + Quantum storage heaters + new HWC	84	£18,650	5,842	combined	combined	578,040	£32.26
Insulation package + DGA + wood log boiler 80% + new HWC	84	£25,550	2,398	combined	combined	769,969	£33.18
Insulation package + DGA + ASHP + new HWC	72	£23,850	3,478	combined	combined	707,619	£33.70
Insulation package + DGA + Solar hot water	54	£20,100	11,221	combined	combined	593,509	£33.87
Insulation package + DGA + Ground Source Heat Pump	79	£28,100	3,006	combined	combined	757,809	£37.08
Solid Wall insulation (U-value 0.3) (SWI)	16	£9,000	24,177	36	0.25	240,678	£37.39
Insulation package + DGA + SF range 67.5% + new HWC	75	£24,350	7,378	combined	combined	636,369	£38.26
Insulation package + DGA + PVs	60	£26,600	10,911	combined	combined	603,294	£44.09
Solid Fuel (SF) range boiler 67.5% + new HWC	26	£8,500	18,813	12	0	171,336	£49.61
Insulation package + DGA + Wind turbine on mast (5m diameter)	92	£35,100	8,729	combined	combined	614,359	£57.13
Insulated doors (2 doors)	1	£1,000	32,429	20	0.15	11,254	£88.86
Low-E + Argon filled Double Glazing (U-value 1.8) (DGA)	4	£4,900	30,775	20	0.15	39,372	£124.45
Low-E Double Glazing (U-value 2.1) (DG)	4	£4,900	30,836	20	0.15	38,335	£127.82
Photovoltaics (2 kWp) (PVs)	3	£11,500	32,374	25	0	17,925	£641.56
Solar hot water panels (4m2)	1	£5,000	32,711	20	0	7,600	£657.89
Wind turbine on stand-alone mast (5m diameter)	13	£20,000	30,192	10	0	28,990	£689.89
Wind turbine on roof (2m diameter)	2	£2,750	32,737	10	0	3,540	£776.84

Improving Energy Efficiency in the Detached Bungalow

4.54 For this dwelling, 65 different single improvement measures or combinations of measures were assessed.

4.55 The increases in the SAP score, the reductions in kg of CO_{2e} emissions, and the reductions in SAP fuel bills are plotted against the mean capital cost of the various improvement measures in Figures 4.2, 4.3 and 4.4 respectively. The capital costs are along the x-axis, and the respective impact on the SAP rating, CO_{2e} emissions and fuel bills on the y-axis. The axes of the graphs take their intersection to be the median of cost of the improvements assessed for this dwelling (i.e. £5,450) and the median change in the respective SAP score (i.e. 43 SAP points), the reduction in Kg of CO_{2e} per year (i.e. 21,604 kg[52] of CO_{2e}), and the reduction in £ per year on the SAP fuel costs (i.e. £1,913). This effectively quarters the graph into low cost - low impact, low cost - high impact, high cost - low impact, and high cost - high impact sections. The further left on the x-axis and further up the y-axis, the bigger the impact on the energy performance of the dwelling for the money spent. Additionally, Figure 4.2 displays threshold lines showing the increase in SAP points to raise this dwelling into a higher SAP banding.

SAP rating: Low cost - High impact improvements in the Detached Bungalow

4.56 Ten improvements comprise in the low cost - high impact sector of the graph in Figure 4.2: mostly heating with loft insulation or loft insulation and draught proofing combinations (see Table 4.7). The cost of increasing the SAP rating by 1 point ranges between £59 and £110 per point amongst this group of measures. Two of the improvements here do not raise the dwelling out of the SAP Band G; with the rest, the dwelling would achieve SAP Band F.

Table 4.7: SAP rating: Low cost - High impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	SAP increase	Saving kg CO_{2e} / year	Cost per SAP point increase
Electric fan storage heating (auto) + new HWC + LI	19	G	£2,500	43	19,663	£58
Electric wet thermal store on off peak E18 tariff + damper	20	G	£4,050	44	19,348	£92
Electric fan storage heating (auto charge control) + new HWC + LI + DP	21	F	£2,600	45	20,104	£58
Oil condensing combi 90.1% + LI	25	F	£5,350	49	24,622	£109
Oil condensing combi 90.1% + LI + DP	26	F	£5,450	50	24,868	£109
Oil condensing combi 90.1% + LI + DGA + DP doors	29	F	£3,900	53	25,332	£74
Quantum storage heaters + new HWC + LI + DP	31	F	£4,000	55	21,948	£73
Insulation package + DGA + Wind turbine on roof (2m diameter)	32	F	£4,400	56	21,817	£79
Electric wet thermal store + LI + DP	33	F	£4,450	57	22,628	£78
Quantum storage heaters + new HWC + LI + DGA + DP doors + FI	38	F	£5,450	62	23,475	£88

[52] In this report, the CO_{2e} figures are reported in kg of CO_{2e} per year for individual dwellings. When they are aggregated for the stock, they are reported in tonnes of CO_{2e} per year (1 tonne = 1,000 kg).

Figure 4.2 Cost of Measure versus Increase in SAP rating

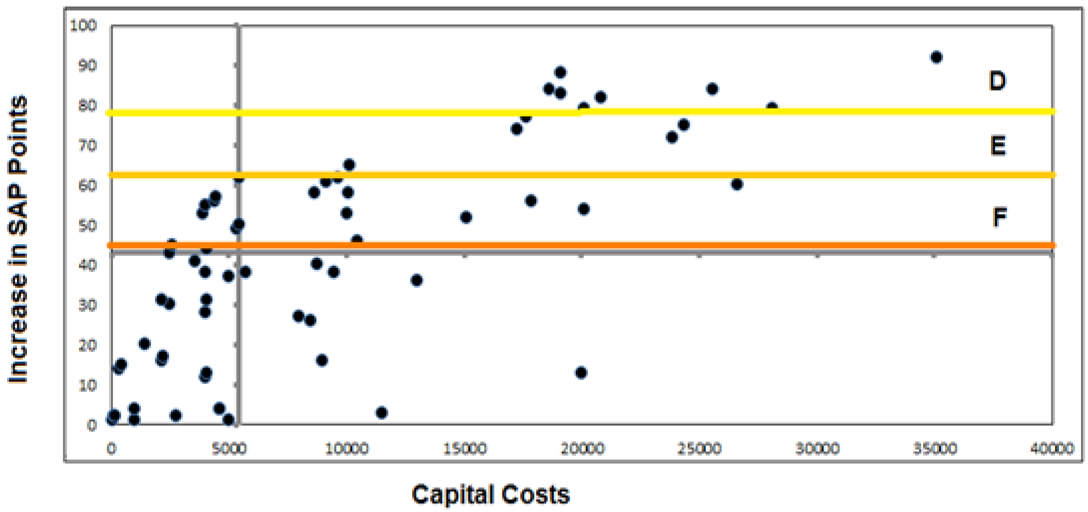


Figure 4.3 Cost of Measure versus Reductions in CO_{2e} emissions

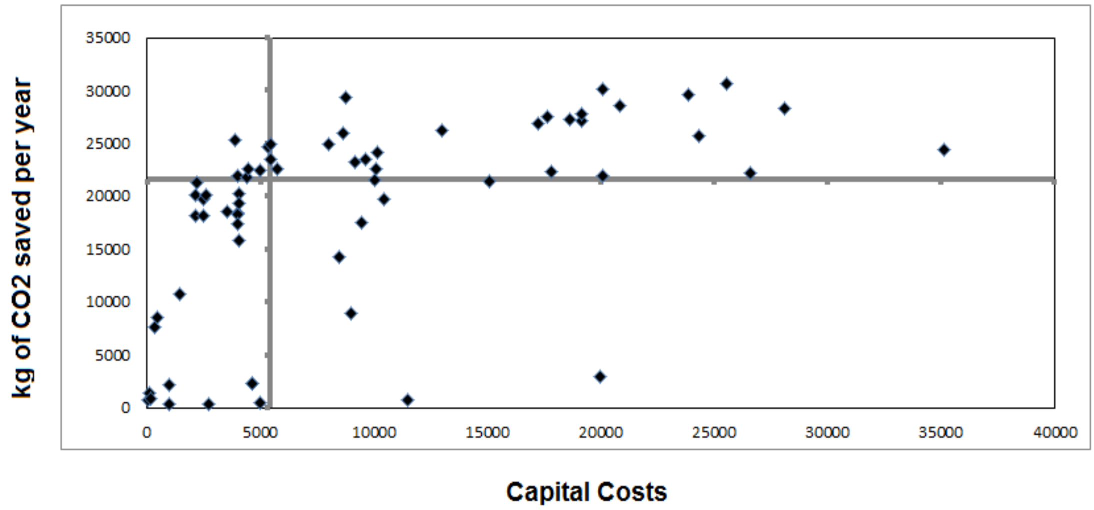
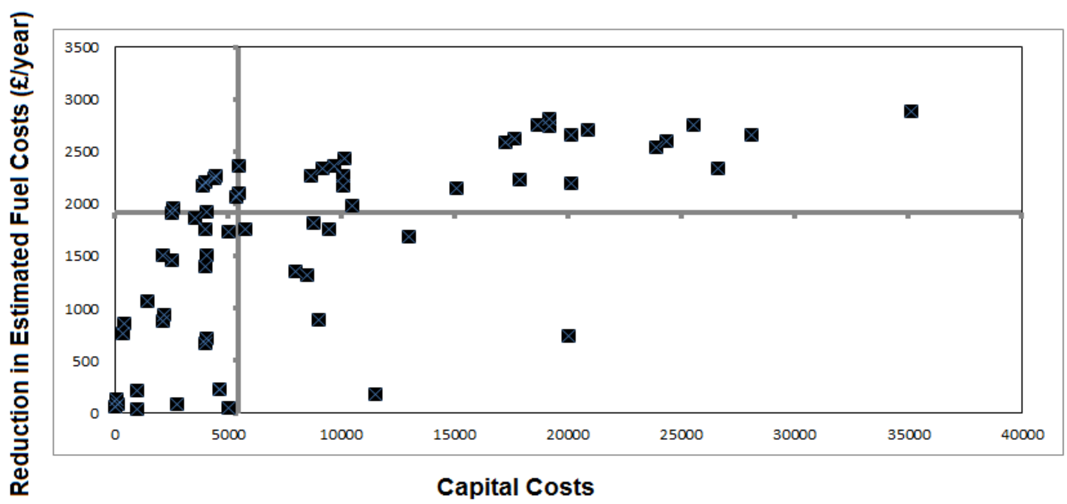


Figure 4.4 Cost of Measure versus Reductions in Estimated Fuel Costs



CO_{2e} emissions: Low cost - High impact improvements in Detached Bungalow

4.57 When examined in terms of the impact on reducing carbon emissions, the Low cost - High impact sector is comprised of heating improvement options (see Table 4.8). Changing from burning house coal in open fires reduces the CO_{2e} emissions from this dwelling. The oil boiler, quantum storage heater, and electric wet thermal store improvements of the Low cost - High impact measures per SAP point again feature amongst the Low cost - High impact sector when costs are assessed against the CO_{2e} emission reductions (see Table 4.8 below). While the new high heat retention electric storage heaters (i.e. Quantum storage heaters) still feature here, the more usual form of storage heating (i.e. the modern slimline storage heaters) drop out of the Low cost - High impact emissions sector. The oil boilers in this section are joined by the condensing combi boiler without any additional insulation being included within the improvement measure. No insulation only package comes within this sector. The mean cost of reducing CO_{2e} by 1 kg per year here ranges between 18p per kg of CO_{2e} up to 24p per kg of CO_{2e} saved.

Table 4.8: CO_{2e} emissions: Low cost - High impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	Saving kg CO_{2e} / year	Cost per kg CO_{2e} reduced
Oil condensing combi 90.1%	13	G	£5,000	22,483	£0.22
Oil condensing combi 90.1% + LI	25	F	£5,350	24,622	£0.22
Oil condensing combi 90.1% + LI + DP	26	F	£5,450	24,868	£0.22
Oil condensing combi 90.1% + LI + DGA + DP doors	29	F	£3,900	25,332	£0.15
Quantum storage heaters + new HWC + LI + DP	31	F	£4,000	21,948	£0.18
Insulation package + DGA + Wind turbine on roof (2m diameter)	32	F	£4,400	21,817	£0.20
Electric wet thermal store + LI + DP	33	F	£4,450	22,628	£0.20
Quantum storage heaters + new HWC + LI + DGA + DP doors + FI	38	F	£5,450	23,475	£0.23

Fuel bill reductions: Low cost - High impact improvements in Detached Bungalow

4.58 As already discussed the SAP scores and SAP fuel bills are directly related, so it is not surprising that the improvement measures comprising Low cost – High impact when examining the reductions in fuel bills are identical to those seen when discussing the impact of the improvements on increasing the SAP scores in paragraph 4.51.

4.59 The Low cost - High impact sector of the Figure 4.4 is comprised of various changes in the heating system usually coupled with loft insulation or loft insulation and draught proofing. The payback periods range between 1.3 and 2.8 years (see Table 4.9). Two of the improvements do not raise the dwelling beyond SAP Band G. The rest of the options assessed raise the dwelling into SAP Band F. The payback periods range between 1.3 and 2.6 years.

Table 4.9: Reduced Fuel Bills: Low cost - High impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost (£)	SAP increase	saving £/year	payback (years)
Electric fan storage heating (auto) + new HWC + LI	19	G	£2,500	43	£1,913	1.3
Electric wet thermal store on off peak E18 tariff + damper	20	G	£4,050	44	£1,923	2.1
Electric fan storage heating (auto charge control) + new HWC + LI + DP	21	F	£2,600	45	£1,959	1.3
Oil condensing combi 90.1% + LI	25	F	£5,350	49	£2,062	2.6
Oil condensing combi 90.1% + LI + DP	26	F	£5,450	50	£2,100	2.6
Oil condensing combi 90.1% + LI + DGA + DP doors	29	F	£3,900	53	£2,173	1.8
Quantum storage heaters + new HWC + LI + DP	31	F	£4,000	55	£2,207	1.8
Insulation package + DGA + Wind turbine on roof (2m diameter)	32	F	£4,400	56	£2,244	2.0
Electric wet thermal store + LI + DP	33	F	£4,450	57	£2,270	2.0
Quantum storage heaters + new HWC + LI + DGA + DP doors + FI	38	F	£5,450	62	£2,365	2.3

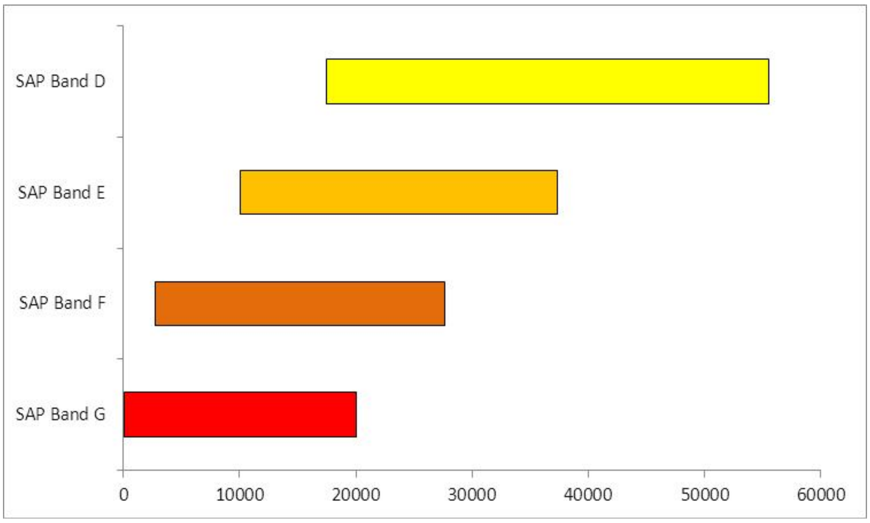
4.60 All of the other improvement measures assessed for this detached bungalow fall within the Low cost - Low impact; High cost - Low impact; and High cost - High impact sections of the respective graphs. An extended analysis is set out in Appendix 9.

Overall Comment on the Improvements Assessed for the Detached Dwelling

4.61 On their own, many of the single measures and many of the insulation-only packages are insufficient to raise the SAP rating of this dwelling out of SAP Band G. With regard to insulation, only the comprehensive insulation package of loft, wall and floor insulation coupled with draught proofing of the windows and doors, just achieves a SAP Band F rating. Achieving even higher SAP bandings would require comprehensive insulation and heating improvement packages. That said, there are a variety of heating options, once coupled with insulation packages that can be selected from, including various options to achieve a SAP rating of '55' or better.

4.62 The indicative cost to achieve a SAP Banding of F ranged between £2,600 (just to reach it) to £26,600; by way of comparison, to achieve a SAP Banding of E, ranged between £10,150 and £23,550; and to achieve a SAP Banding of D ranged between £19,150 and £35,100. Conversely, given the range of measures assessed here, it is possible to spend more than £20,000 and still be a SAP Band G dwelling. Alternatively, if you chose to spend up to £19,150 on this property, you could achieve a SAP rating in Band D. The ranges of indicative costs to achieve the different SAP bandings in this dwelling are illustrated in Figure 4.5.

Figure 4.5: Detached Dwelling: Range of Costs to Achieve a SAP Band Rating



4.63

4.64 Importantly, this dwelling would be considered one of the most problematic to improve. It is a detached bungalow, and therefore comprises a relatively high amount of exposed heat loss surface area for its floor area and volume, and was noted to be problematic within the EESSH modelling works[53]. It is comprised of walls that would need expensive insulation to improve their energy efficiency performance. The dwelling is well-off the gas grid. If a SAP D band rating can be achieved here, it should be easier and cheaper elsewhere in the stock.

Improving the Top Floor Flat

4.65 A similar analysis was performed on a 1920's solid wall tenemental gable end flat within an urban area of Scotland. This dwelling has brick walls to the gable and rear, and sandstone walls to the front. It does have double glazing. It has no loft insulation. It is heated via direct acting electric heaters, and its hot water is provided via a single electric immersion heater in a poorly insulated hot water cylinder. There are no low energy light bulbs in the dwelling. The windows are draught proofed; the door is not. The flat does have a mains gas meter supply point. The starting point of this dwelling is a SAP rating of '4'. The improvements assessed for this dwelling are set out in Table 4.10.

4.66 What emerges immediately is that compared to the detached bungalow, the presence of a gas supply in this dwelling completely changes the dynamics of the improvements. For example, simply fitting a gas condensing combi boiler as a single measure increases the SAP score from '4' to '55', and in itself raise the SAP rating from Band G to Band D. Two of the improvement packages assessed raise the SAP rating into Band C.

[53] In para 3.8 of the ‘Developing an Energy Efficiency Standard for Social Housing: A Consultation’ (2012, p9), it states “In one particular instance, (detached houses and bungalows with electrical space heating), the proposed standard is below that expected for the SHQS to reflect the difficulty of reaching the requires energy efficiency rating of 60 for such properties.”

Table 4.10: Top Floor Flat Improvement Options - Rank ordered by SAP score

Improvement assessed	SAP	EPC Band	Capital cost £)	CO_{2e} /year	Fuel Bill (£ / year)
Base case	*4*	*G*		*6,544*	*£1,663*
Low energy light bulbs (LELs)	5	G	£25	6,486	£1,648
Draught proofing door (DPd)	5	G	£100	6,532	£1,660
Insulated door (U-value 1.0)	5	G	£500	6,443	£1,637
Hot water tank jacket 80mm (HWTJ)	5	G	£23	6,327	£1,608
Wind turbine on roof (2m diameter)	5	G	£2,750	6,431	£1,634
Low-e + Argon-filled DG (U-value 1.8) (DGA)	6	G	£4,900	6,419	£1,631
Solar hot water ($4m^2$)	9	G	£5,000	5,978	£1,519
Photovoltaics (2 kWp)	11	G	£11,500	5,827	£1,481
Solid Wall insulation (U-value 0.3) (SWI)	18	G	£9,000	5,072	£1,289
Electric storage heating system auto control on E7 (ESH E7)	20	G	£1,400	7,808	£1,247
Loft insulation (U-value 0.13) (LI)	22	F	£350	4,652	£1,182
LI + DPd	22	F	£450	4,640	£1,179
ESH E7 + HWTJ	22	F	£1,423	7,268	£1,182
LI + DPd + HWTJ	25	F	£478	4,427	£1,125
LI + DPd + HWTJ + CFLs	26	F	£498	4,371	£1,111
Electric storage heating system auto control on E24 (ESH E24)	29	F	£1,600	7,415	£1,034
ESH E24 + HWTJ	30	F	£1,623	7,273	£1,014
Quantum storage heaters	31	F	£2,800	6,354	£1,004
Air source heat pump (ASHP) + new Hot water cylinder	34	F	£8,500	3,758	£955
Quantum storage heater + HWTJ	35	F	£2,823	6,137	£934
ESH E7 + LI	36	F	£1,750	5,258	£904
ESH E7 + LI + DPd	37	F	£1,850	5,242	£902
ESH E7 + LI + DPd + HWTJ	40	E	£1,878	5,058	£837
ESH E7 + LI + DPd + HWTJ + CFLs	42	E	£1,898	5,014	£818
Quantum storage heaters + LI	45	E	£3,150	4,508	£774
Quantum storage heaters + LI + DPd	45	E	£3,250	4,497	£772
ESH E24 + LI	47	E	£1,950	5,066	£739
ESH E24 + LI + DPd	47	E	£2,050	5,052	£737
Insulation package (LI SWI DPd LELs HWTJ)	49	E	£9,498	2,804	£712
ESH E24 + LI + DPd + HWTJ	49	E	£2,073	4,859	£712
Quantum storage heaters + LI + DPd + HWTJ	50	E	£3,273	4,282	£702
ESH E24 + LI + DPd + HWTJ + CFLs	50	E	£2,098	4,811	£695
ASHP + LI	50	E	£8,850	2,736	£695
ASHP + LI + DPd	50	E	£8,950	2,729	£694
Insulation package + Wind turbine on roof (2m diameter)	51	E	£12,248	2,690	£684
Quantum storage heaters + LI + DPd + HWTJ + CFLs	51	E	££3,298	4,227	£682
ASHP + LI + DPd + CFLs	52	E	£8,975	2,657	£675
Gas condensing combi 88% (GCC)	55	D	£5,000	3,041	£626
Insulation package + Solar hot water	55	D	£14,498	2,456	£624
GCC + Flue Gas Heat Recovery System (FGHRS)	56	D	£5,450	2,921	£612
Insulation package + ESH E7	61	D	£10,898	3,031	£552
Insulation package + PVs	62	D	£20,998	2,087	£530
GCC + LI	65	D	£5,350	2,193	£494
GCC + LI + DPd	65	D	£5,450	2,188	£493
Insulation package + Quantum storage heaters	65	D	£12,298	2,717	£493
GCC + LI + DPd + CFLs	66	D	£5,475	2,112	£473
Insulation package + ASHP	67	D	£11,798	1,806	£459
Insulation package + ESH E24	67	D	£11,098	2,960	£459
Insulation package + GCC	74	C	£14,498	1,407	£359
Insulation package + GCC + FGHRS	75	C	£14,498	1,335	£347

4.67 In Table 4.11, the indicative capital cost of the improvement options are set out alongside the changes in the SAP ratings, the reduction in CO_{2e} emissions and the reductions in fuel bills for each improvement option. In the last three columns of Table 4.11 below, the relative cost of a single point increase in the SAP rating, the cost of reducing CO_{2e} emissions by 1 kg per year, and the payback of the measures are set out as well. These relative costs vary considerably.

Table 4.11: Impact and Cost of Improvements - Top Floor Flat

Improvement assessed	Capital cost (£)	Increase in SAP score	saving kg CO_{2e} / year	saving in fuel bill £/year	Cost per SAP point increase (£)	Cost per Kg CO_{2e} saved per year (£)	Payback (years)
Base case							
Low energy light bulbs (LELs)	£25	1	58	£15	£25	£0.43	1.7
Draught proofing door (DPd)	£100	1	12	£3	£100	£8.33	33.3
Insulated door (U-value 1.0)	£500	1	101	£26	£500	£4.95	19.2
Hot water tank jacket 80mm (HWTJ)	£23	1	217	£55	£23	£0.11	0.4
Wind turbine on roof (2m diameter)	£2,750	1	113	£29	£2,750	£24.34	94.8
Low-e + Argon-filled DG (U-value 1.8) (DGA)	£4,900	2	125	£32	£2,325	£37.20	145.3
Solar hot water (4m^2)	£5,000	5	566	£144	£1,000	£8.83	34.7
Photovoltaics (2 kWp)	£11,500	7	717	£182	£1,642	£16.04	63.2
Solid Wall insulation (U-value 0.3) (SWI)	£9,000	14	1,472	£374	£642	£6.11	24.1
Electric storage heating system auto control on E7 (ESH E7)	£1,400	16	-1,264	£416	£87	-£1.11	3.4
Loft insulation (U-value 0.13) (LI)	£350	18	1,892	£481	£19	£0.18	0.7
LI + DPd	£450	18	1,904	£484	£25	£0.24	0.9
ESH E7 + HWTJ	£1,423	18	-724	£481	£79	-£1.97	3.0
LI + DPd + HWTJ	£478	21	2,117	£538	£23	£0.23	0.9
LI + DPd + HWTJ + CFLs	£498	22	2,173	£552	£23	£0.23	0.9
Electric storage heating system auto control on E24 (ESH E24)	£1,600	25	-871	£629	£64	-£1.84	2.5
ESH E24 + HWTJ	£1,623	26	-729	£649	£62	-£2.23	2.5
Quantum storage heaters	£2,800	27	190	£659	£104	£14.74	4.2
Air source heat pump (ASHP) + new Hot water cylinder	£8,500	30	2,786	£708	£283	£3.05	12.0
Quantum storage heater + HWTJ	£2,823	31	407	£729	£91	£6.94	3.9
ESH E7 + LI	£1,750	32	1,286	£759	£55	£1.36	2.3
ESH E7 + LI + DPd	£1,850	33	1,302	£761	£56	£1.42	2.4
ESH E7 + LI + DPd + HWTJ	£1,878	36	1,486	£826	£52	£1.26	2.3
ESH E7 + LI + DPd + HWTJ + CFLs	£1,898	38	1,530	£845	£50	£1.24	2.2
Quantum storage heaters + LI	£3,150	41	2,036	£889	£77	£1.55	3.5
Quantum storage heaters + LI + DPd	£3,250	41	2,047	£891	£79	£1.59	3.6
ESH E24 + LI	£1,950	43	1,478	£924	£45	£1.32	2.1
ESH E24 + LI + DPd	£2,050	43	1,492	£926	£48	£1.37	2.2
Insulation package (LI SWI DPd LELs HWTJ)	£9,498	45	3,740	£951	£211	£2.54	10.0
ESH E24 + LI + DPd + HWTJ	£2,073	45	1,685	£951	£46	£1.23	2.2
Quantum storage heaters + LI + DPd + HWTJ	£3,273	46	2,262	£961	£71	£1.45	3.4

Improvement assessed	Capital cost (£)	Increase in SAP score	saving kg CO_{2e} / year	saving in fuel bill £/year	Cost per SAP point increase (£)	Cost per Kg CO_{2e} saved per year (£)	Payback (years)
ESH E24 + LI + DPd + HWTJ + CFLs	£2,098	46	1,733	£968	£46	£1.21	2.2
ASHP + LI	£8,850	46	3,808	£968	£192	£2.32	9.1
ASHP + LI + DPd	£8,950	46	3,815	£969	£195	£2.35	9.2
Insulation package + Wind turbine on roof (2m diameter)	£12,248	47	3,854	£979	£261	£3.18	12.5
Quantum storage heaters + LI + DPd + HWTJ + CFLs	£3,298	47	2,317	£981	£70	£1.42	3.4
ASHP + LI + DPd + CFLs	£8,975	48	3,887	£988	£187	£2.31	9.1
Gas condensing combi 88% (GCC)	£5,000	51	3,503	£1,037	£98	£1.43	4.8
Insulation package + Solar hot water	£14,498	51	4,088	£1,039	£284	£3.55	14.0
GCC + Flue Gas Heat Recovery System (FGHRS)	£5,450	52	3,623	£1,051	£105	£1.50	5.2
Insulation package + ESH E7	£10,898	57	3,513	£1,111	£191	£3.10	9.8
Insulation package + PVs	£20,998	58	4,457	£1,133	£362	£4.71	18.5
GCC + LI	£5,350	61	4,351	£1,169	£88	£1.23	4.6
GCC + LI + DPd	£5,450	61	4,356	£1,170	£89	£1.25	4.7
Insulation package + Quantum storage heaters	£12,298	61	3,827	£1,170	£202	£3.21	10.5
GCC + LI + DPd + CFLs	£5,475	62	4,432	£1,190	£88	£1.24	4.6
Insulation package + ASHP	£11,798	63	4,738	£1,204	£187	£2.49	9.8
Insulation package + ESH E24	£11,098	63	3,584	£1,204	£176	£3.10	9.2
Insulation package + GCC	£14,498	70	5,137	£1,304	£207	£2.82	11.1
Insulation package + GCC + FGHRS	£14,498	71	5,209	£1,316	£204	£2.78	11.0

4.68 Another occurrence seen within Table 4.11, not seen in the analysis of the detached dwelling, is the appearance of negative CO_{2e} emission values, that is, CO_{2e} emissions are increasing when compared against the base case top floor flat. This increase occurs because of the change from direct electric heating in the base case, and the modelling of the impact of electric storage heating. Although both types of heating are deemed 100% efficient at end-use in the home, storage heaters are considered an unresponsive heating system, while direct electric heaters are considered responsive in SAP. Unresponsive heating systems are penalised within SAP and RdSAP by increasing the energy consumption associated with heating the dwelling, when compared to responsive heaters. However, this extra consumption is charged on the lower, off-peak electricity tariff rate within SAP and RdSAP so replacing direct electric on-peak heaters with electric storage off-peak heaters results in a fuel cost saving and a better SAP rating despite the increase in energy consumption and the increase in the associated CO_{2e} emissions.

Improving the Energy Efficiency in the Top Floor Flat

4.69 The increases in the SAP score, the reductions in kg of CO_{2e} emissions, and the reductions in SAP fuel bills are plotted against the indicative capital cost[54]

[54] calculated using the values set out in Table 4.2 and Table 4.2a above

of the various improvement options assessed for this top floor tenemental flat in Figures 4.6, 4.7 and 4.8 respectively. The capital costs are along the x-axis, and the respective impact on the SAP rating, CO_{2e} emissions, and fuel costs are on the y-axis. The axes of the graphs take their intersection to be the median cost of the improvement options assessed for this top floor flat (i.e. £3262) and the median change in the respective SAP score (i.e. 41 SAP points), the reduction in kg of CO_{2e} per year (i.e. 1970 kg of CO_{2e}), and the reduction in £ per year on the SAP fuel costs (i.e. £890), quartering the graph into Low cost - Low impact, Low cost - High impact, High cost - Low impact, and High cost - High impact sections. The further left on the x-axis and further up the y-axis, the bigger the impact on the energy performance of the dwelling for the money spent.

4.70 Additionally in Figure 4.6, threshold lines are included showing the increases in SAP points to move this dwelling into the higher SAP Bands.

Figure 4.6: Cost of Measure versus Increase in SAP rating - Top Floor Flat

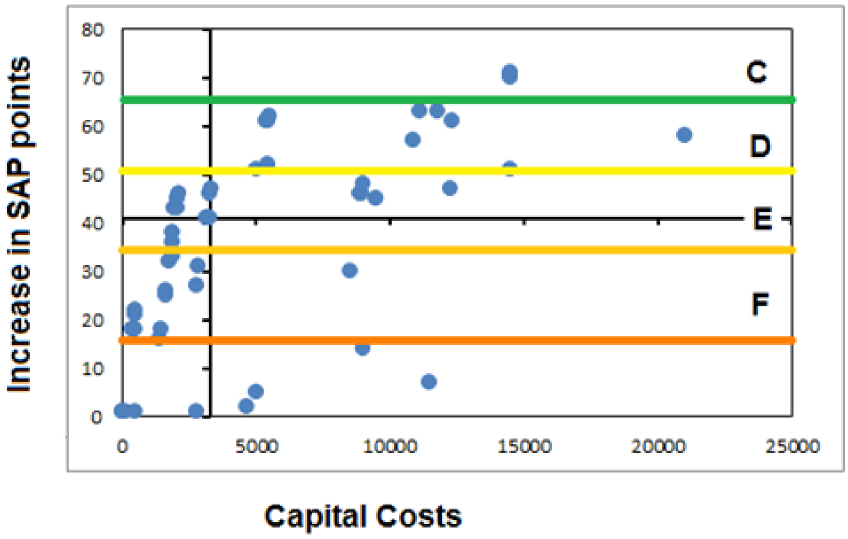


Figure 4.7: Cost of Measure versus Change in CO_{2e} emissions - Top Floor Flat

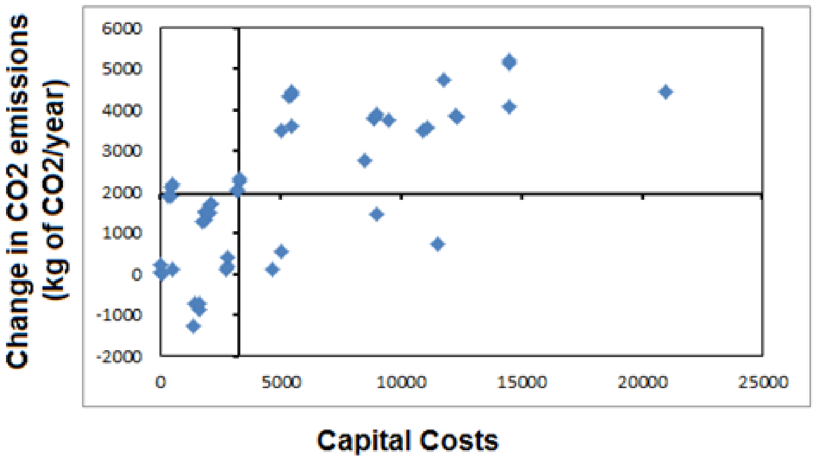
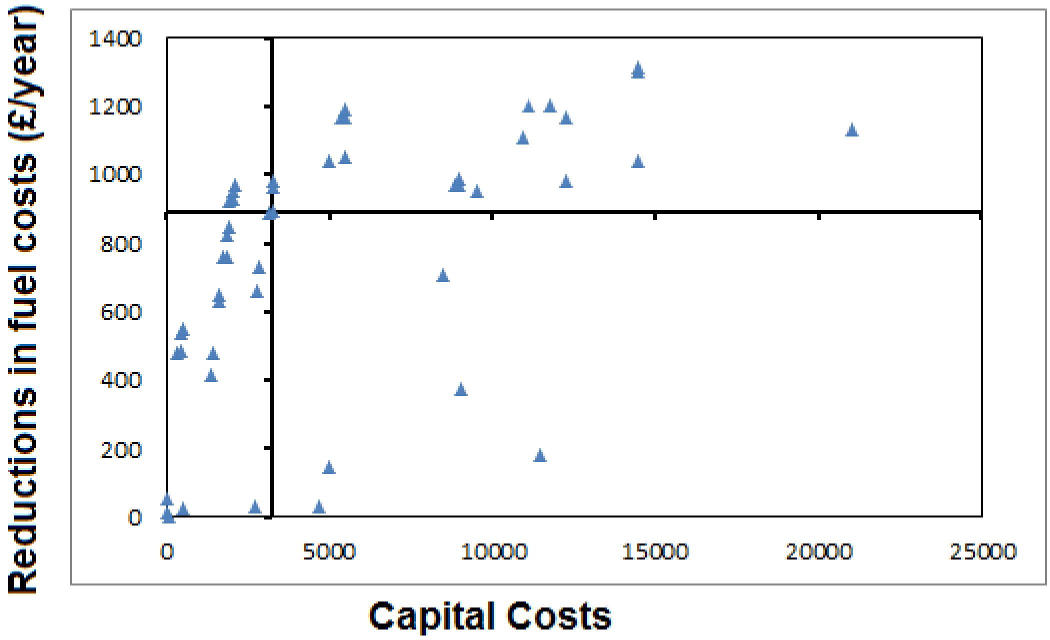


Figure 4.8 Cost of Measure versus Reductions in Fuel Costs - Top Floor Flat



Low cost - High impact improvements in Top Floor Flat

4.71 Only one measure falls within the Low cost - High impact section of the graph for improving the SAP rating, reducing CO_{2e} emissions and cutting household fuel costs - the fitting of the new high thermal capacity (Quantum) electric storage heaters in conjunction with loft insulation and draught proofing the door of the flat (see Tables 4.12 – 4.14 below). A modern electric storage heating system on a 24-hour tariff, coupled with loft insulation, draught proofing the front door, and fitting a new hot water cylinder jacket, show up well on improving the SAP score and reducing the fuel bill, but are not so good on reducing CO_{2e} emissions because of the higher CO_{2e} conversion co-efficient with electric heating than gas.

Table 4.12: SAP rating: Low cost - High impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Increase in SAP score	Cost per SAP point increase (£)
Quantum storage heaters + LI	45	E	£3,150	41	£77
Quantum storage heaters + LI + DPd	45	E	£3,250	41	£79
ESH E24 + LI	47	E	£1,950	43	£45
ESH E24 + LI + DPd	47	E	£2,050	43	£48
ESH E24 + LI + DPd + HWTJ	49	E	£2,073	45	£46
ESH E24 + LI + DPd + HWTJ + CFLs	50	E	£2,098	46	£46

Table 4.13: CO_{2e} emissions: Low cost - High impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Saving kg CO_{2e} / year	Cost per Kg CO_{2e} saved per year (£)
LI + DPd + HWTJ	25	F	£478	2,117	£0.23
LI + DPd + HWTJ + CFLs	26	F	£498	2,173	£0.23
Quantum storage heaters + LI	45	E	£3,150	2,036	£1.55
Quantum storage heaters + LI + DPd	45	E	£3,250	2,047	£1.59

Table 4.14: Fuel Cost Savings: Low cost - High impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Saving in fuel cost (£/year)	Payback (years)
Quantum storage heaters + LI + DPd	45	E	£3,250	£891	3.6
ESH E24 + LI	47	E	£1,950	£924	2.1
ESH E24 + LI + DPd	47	E	£2,050	£926	2.2
ESH E24 + LI + DPd + HWTJ	49	E	£2,073	£951	2.2
ESH E24 + LI + DPd + HWTJ + CFLs	50	E	£2,098	£968	2.2

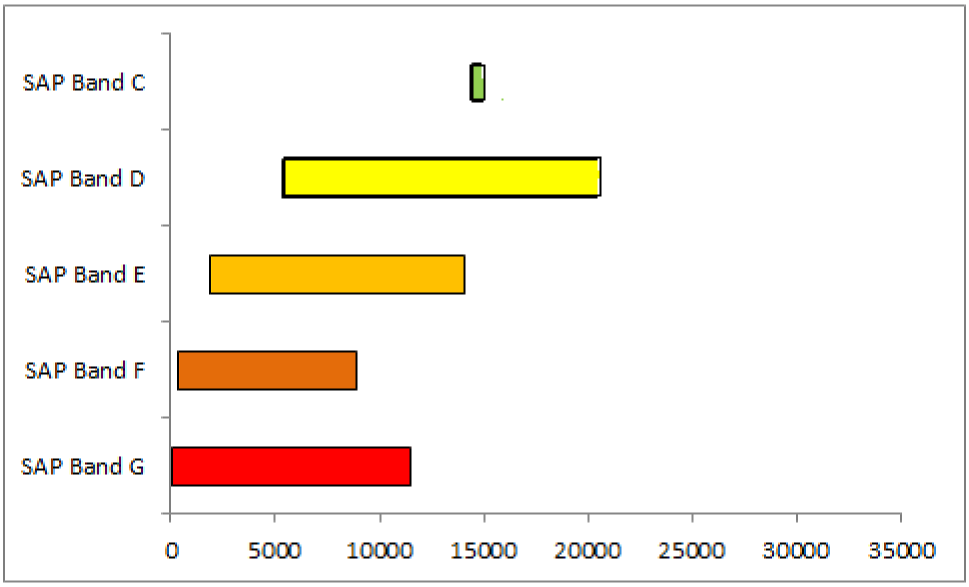
4.72 All of the other improvement measure assessed for this top floor flat fall within the Low cost - Low impact, High cost - Low impact and High cost - High impact sections of the three graphs Low cost - High impact sections of the respective graphs. An extended analysis is set out in Appendix 9.

Overall Comment on the Improvements Assessed for the Top Floor Flat

4.73 The presence of a mains gas supply changes the fundamental nature of the improvement package compared to the assessment of the detached bungalow that was off the gas grid. Installing a condensing boiler as a single measure would achieve a SAP D Band rating, and in combination with insulation measures could achieve a C rating.

4.74 In the top floor tenemental flat, the cost to achieve a SAP Banding of F ranged between £350 to almost £8,500; by way of comparison, to achieve a SAP Banding of E, ranged between £1,878 and £12,248; to achieve a SAP Banding of D ranged between £5,350 and £20,998, and to reach a SAP C rating, between £14,458 and £14,998 (see Figure 4.9). Conversely, given the range of measures assessed here, it is possible to spend upwards of £11,500 and still be a SAP Band G dwelling. Alternatively, if you chose to spend up to £8,500 on this property, you could achieve a SAP rating in Band G, Band F, Band E or Band D.

Figure 4.9: Detached Dwelling: Range of Costs to Achieve a SAP Band Rating



4.75 On its own, loft insulation would be sufficient to raise the SAP rating of this flat to Band F. Wall insulation does not quite achieve a SAP F Band rating on its own here because it was assumed that the close wall would not be insulated.

4.76 While replacing the heating with a gas condensing boiler has the biggest single impact on the energy performance of this dwelling, there were other heating options that had significant impacts on improving the SAP rating, reducing CO_{2e} and lowering fuel bills. Interestingly, switching from the direct electric heaters to electric storage heating (without any complementary insulation) resulted in increased CO_{2e} emissions although the option improved the SAP rating and lowered fuel bills.

4.77 There is a general consistency with the measures emerging from the assessment falling into the respective Low cost - High impact, Low cost - Low impact, High Cost - High impact, and High cost - Low impact groupings for this property.

4.78 There is also consistency within this dwelling that some measures are extremely cost effective but do not have a huge impact in terms of raising the overall SAP rating. There is also a consistency in measures that are very expensive and do not make a sizeable big impact on the rating, or the reductions in CO_{2e} emissions, and have a long payback period.

Establishing a hierarchy for modelling improvements

4.79 The lessons emerging from the analysis of the improvement options assessed for the detached bungalow and the top floor tenemental flat are:

- that the prevailing situation in terms of the installed heating, insulation, ventilation and presence of other energy saving equipment within the dwelling, the location of the dwelling (whether on or off the gas grid) were important variables in determining the applicability of potential improvement measures, and how effective they will be at improving the SAP rating, reducing the CO_{2e} emissions and lowering the fuel costs;

- that certain measures may be very cost effective but will have only a small impact on the overall improvement of the SAP rating
- that certain measures are very expensive, not cost effective and will only have a very small impact on the SAP rating
- that for a particular dwelling there is a great consistency amongst the measures that can be categorised as Low cost - High impact, Low cost - Low impact, High Cost - High impact, and High cost - Low impact.
- that it is likely that a package of measures to raise the SAP rating to achieve a SAP Band D rating would be possible in most dwellings, as well as the lower bandings.

4.80 While the quadrant-based analysis was very useful for highlighting these issues, it was deemed too subjective overall on the basis of defining the overall hierarchy of improvements. The intersections of the improvement in SAP scores and the indicative capital costs axes would change with each archetype modelled and depend on the range of improvements modelled.

4.81 The results from the modelling of the two sample dwellings highlighted that there was a high degree of variability with regard to the impact of different improvements. While the intention of the hierarchy of improvements was to include measures that were 'cost effective', the issue for this project became one of 'what is cost effective'? As can be seen from the above discussions, there are no shortage of ways to measure or define cost-effectiveness:

- increase in SAP points
- SAP points increase per £
- increase in Environmental Impact rating
- reduction in CO_{2e} emissions
- tonnes of CO_{2e} reduction per £
- reductions in fuel costs
- minimum payback periods

4.82 Alternatives to some measure of cost effectiveness were discussed, for example;

- maximum cap on the capital cost of improvements
- minimum standards to be met

4.83 Alternative monetary approaches assessed included calculating the fuel cost savings over the lifetime of the improvement and comparing it with the cost of the improvement either directly, or by discounting the fuel cost savings (e.g. using the Ofgem 'in-use' factors[55]). The net return on the investment over the

[55] See para 5.50 for more discussion about in-use factors and ‘the rebound effect’.

lifetime of the investment was modelled. The complicating issue here is that different measures have different lifetimes and different in-use factors. This means that a combined lifetime has to be calculated, with the savings associated with each improvement within a package being affected by the order in which the improvement measures are assessed.

4.84 In addition to examining the monetary return, another approach calculated the cost of a net lifetime tonne of CO_{2e} saved by the various improvement measures and package. This approach again took into account the lifetime of the measure and its 'in-use' factor. This cost could be compared with the shadow price of carbon figures that are published by the government.

4.85 That said, in assessing a measure, a view with regards to not closing off future options will be applied. For example, the Scottish Government not only has a greenhouse gas emissions reduction target for 2020, but also a more onerous one for the year 2050. Thus, for example, if it were necessary to propose external wall insulation to achieve a target SAP score (regardless of the banding), it would be inappropriate to improve the wall U-value by the minimum necessary just to achieve that banding. Trying to then further improve the U-value at a later date to achieve the next target would incur duplication of effort, extra costs and be less cost effective. Similarly, the same could be said for any insulation measure. So where insulation is to be proposed, the proposal would be to achieve at least the minimum standard in keeping with the current Scottish building regulations.

4.86 This issue is less of a concern with heating. The lifetime of heating systems is less than that of fabric insulation[56], so going for a short term system such as gas would be to reap the short term gains in terms of improvements in energy efficiency, reductions in CO_{2e} emissions, and the fall in fuel bills, knowing that in the medium term future they are going to be replaced anyway. If gas is still a low cost, low carbon fuel in 2030, then nothing is lost. If the de-carbonisation of electricity supply means the future is electric, then when these heating systems are in need of replacement, new heating can be installed.

4.87 Installing wet central heating systems, certainly within urban areas, would be in keeping with the proposed establishment of heat generation networks in Scotland. These networks will take time to establish, and ultimately switching the heat source from an individual boiler to a connection to a community heat network would not be disadvantaged by the presence of a wet distribution network (radiators and pipework) already within the dwelling.

4.88 Lastly, in keeping with the principles set out within the proposed Scottish Heat Generation Strategy, even where a single heating measure would be sufficient to achieve the target SAP banding set for REEPS, the dwelling should be brought up to a minimum insulation standard. Reducing the demand for heat, by reducing the heat loss from our dwellings would reduce the pressure of rising fuel bills on households.

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[56] Ofgem's lifetime guidance for ECO is 12 years for a wet central heating system, and 20 years for electric storage heating.

4.89 Within all of this discussion, what has become apparent is that all of the energy performance indicators do not always move in the same way. Sometimes they do: the improvement measure reduces fuel costs, reduces energy consumption and reduces CO_{2e} emissions, while improving the energy performance rating of the dwelling. In other instances, for example, you can achieve improved SAP ratings and reductions in fuel costs, but at the cost of higher energy consumption or higher CO_{2e} emissions. Alternatively, you can achieve lower CO_{2e} emissions and reduce the dwelling's SAP score. Most insulation improvement measures, regardless of their cost effectiveness, have a limited impact on increasing the SAP score when pursued as single measures. Large improvements in SAP ratings can be achieved by focussing on heating related improvements, but such an emphasis would result in higher energy consumption if not pursued in tandem with insulation improvements. For any given amount of capital expenditure, the impact on the dwelling's energy performance will be dependent on the actual improvements selected; a large capital expenditure is no guarantee that a large improvement in the SAP rating will result.

4.90 The RAG decided that the issue that would engender the most public concern and be the focus of the public debate, if REEPS became a mandatory standard, related to the capital cost of the improvements. That is, the public would be concerned with "how much is this going to cost me?" The decision taken by the REEPS RAG was for the modelling of the 355 individual archetypes to identify the cheapest selection of improvement measures to take each dwelling into the successive SAP bandings, from SAP Band G to Band F, from SAP Band F to Band E, and from SAP Band E to Band D. If REEPS becomes a mandatory standard, the current policy intention is for the public to have flexibility in deciding how to meet the standard.

4.91 On this basis, a 5-page report was prepared for each of the 355 archetypes. An example of the 5-page report is included below for archetype 1320130. Each report follows the same format, and contains:

- **a description of the archetype**: Archetype 1320130 presented represents the group of pre-1919 mid terrace / terrace with passage / enclosed end dwelling with sandstone walls and a mains gas boiler and achieved a Band F rating (as set out in the title). This group represents 1684 dwellings (i.e. 0.42%) of the target stock. Specifically, the actual dwelling modelled was a mid-terrace bungalow with rooms in the roof and an extension. All of the dimensional details used in the modelling and U-values are set out on the description page, along with information on the space heating, hot water and controls in the dwelling, and other energy-related characteristics of the dwelling when surveyed by the SHCS. This dwelling has an assessed SAP 2012 score of 30, so falls into SAP Band F.
- **the list of the specific improvements modelled for the archetype:** On the second page of the report, the resultant SAP and Environmental Impact scores and bandings, as well as the SAP fuel costs, CO2e emissions and delivered energy consumption figures broken down by energy end use in the home for each of the improvements modelled for the respective archetype. The improvements modelled were specific to this

dwelling in this archetype, and were drawn from the overall list of 38 improvements measures set out earlier in this report (see para 4.11 – 4.17, and described in more detail in Appendix 2). For this dwelling, 19 improvement measures were modelled as individual improvements, and ordered according to their impact on the SAP score. The impact of two of the improvements are sufficient enough in their own right to increase the SAP score by at least SAP 9 points, which would move the dwelling from SAP Band F into Band E. None of the other improvements assessed increase the SAP score by as many as 9 points.

- **the list of the improvements not assessed and the reason:** the third page of the report sets out the reasons why specific improvements were not modelled for this archetype. Some improvements were not applicable to archetype 1320130: for example, flat roof insulation was not assessed because this archetype did not have a flat roof. Some improvements were not recommended: for example, switching to any of the electric heating options would have resulted in a lower SAP score. Some improvements were not needed as they were already present within the dwelling: for example, the existing heating system had a programmer and TRVs already.
- **the impact of the individual improvements on the annual and lifetime SAP fuel costs, CO2e emissions and delivered energy:** The fourth page of the report sets out in Table 3 the calculated annual and lifetime reductions in SAP fuel costs, CO_{2e} emissions and delivered energy for each if the individual improvements. Importantly, these impacts are ordered by the indicative capital cost of the improvement. For archetype 1320130, the improvement measures modelled ranged from £23 for fitting a new hot water cylinder jacket to £20,000 for installing a stand-alone, 5 meter diameter wind turbine. The table also includes the calculated net lifetime return on the investment and its simple payback period. The paybacks vary from 1.1 years to over 350 years: some of the improvements show a positive return on their indicative capital investment cost, while some measures do not recoup the cost of their investment through reductions in SAP fuel costs over the assessed lifetime of the improvement (which are highlighted in orange in Table 3).
- **the cheapest improvement or packages of improvements to raise the SAP banding respectively to SAP Band F, to SAP Band E and to SAP Band D as necessary:** For archetype 1320130, its initial SAP score achieved a SAP Banding of F. Two measures were sufficient on their own to achieve Band E, i.e. loft insulation and a room in the roof insulation package, with loft insulation having a much lower indicative capital cost than the room in the roof insulation package. Loft insulation as a single measure was also less expensive than any combination of other measures to achieve SAP Band E, so loft insulation, with an indicative capital cost of £350, is presented in Table 4a below least costly way to achieve SAP Band E. However, to raise the SAP rating by 25 points, to move it from Band F to Band D needed a combination of improvements. No single measure assessed on its own for archetype 1320130 was sufficient to achieve the 25 point increase in the SAP score necessary to achieve SAP Band D. Many different permutations of improvements could be packaged

to achieve a SAP Band D score of at least 55 here. For archetype 1320130 the package with the least indicative cost included room in the roof insulation, a replacement gas condensing boiler, and a hot water tank jacket. The indicative capital cost for the package was £4723, with a net lifetime return of over £4 for each pound invested, and a simple payback of 7 years.

4.92 Appendix 11 of this report sets out the complete process of taking the initial SHCS data for archetype 1320130 through to the production of its archetype template. All 355 archetype reports are available on-line.

Archetype: **1320130** Archetype Description: **pre1919, mid terrace / terrace with passage enclosed end dwelling, sandstone walls, mains gas boiler, F**

This archetype represents **1684** dwellings, which accounts for approximately **0.42%** of the target dwelling stock

property type:	**mid terrace bungalow with room in roof and extension**					room in roof area:	**35m²**		
age:	**built c.1890**	extension age: **c.1960**		room in roof age: **c.1890**		flat ceiling area	**35m²**	U-value:	**2.3**
number of storeys:	**1**					stud walls	**18.6m²**	U-value:	**2.3**
extensions:	**1**		number of habitable rooms:	**4**		sloping ceiling	**18.6m²**	U-value:	**2.3**
rooms in the roof:	**yes**		number of heated habitable rooms:	**4**		gables	**15.9m²**	U-value:	**1.41**

total floor area:	**97m² internal**				
main house heat loss floor area:	**44m²**	main house floor construction:	**suspended not timber, no insulation**	U-value:	**0.68**
extension 1 heat loss floor area:	**18m²**	extension floor construction:	**solid, no insulation**	U-value:	**0.82**
main house gross heat loss wall area:	**53m²**	main house wall construction:	**450-750mm sandstone wall, as built**	U-value:	**1.41**
extension gross heat loss wall area:	**30m²**	extension wall construction:	**cavity wall, no insulation**	U-value:	**1.6**
main house heat loss roof area:	**9m²**	main house roof construction:	**pitched, no insulation**	U-value:	**2.3**
extension heat loss roof area:	**18m²**	extension roof construction:	**pitched, no insulation**	U-value:	**2.3**
glazed area:	**14.44m²**	glazing type:	**80% wood / upvc double glazed, pre2003**	U-value:	**2.8**

main heating: **post1998 Ideal Mexico fan assisted standard boiler** main heating fuel: **mains gas** main heating SAP efficiency: **74.0%**
main heating controls: **programmer and TRVs**

secondary heating: **room heater** secondary heating fuel: **electricity** secondary heating efficiency: **100%**

hot water provision: **from primary heating**
hot water cylinder: **yes** cylinder size: **120 litres** cylinder insulation: **30mm spray foam** cylinder thermostat: **yes**

chimneys:	**3**	electricty meter:	**single**
flues:	**0**	gas meter:	**yes**
extract fans:	**0**		
draught lobby:	**no**	percentage of low energy lighting:	**30%**
draughtproofing:	**80% windows** **0% doors**		

EPC Band	**F**	Environmental Impact Band:	**F**
EPC Score	**30**	Environmental Impact Score:	**27**

These characteristics were modelled in SAP 2012 to create the base case dwelling for this archetype. A number of single improvements were modelled against the base case dwelling to assess their impact on the EPC band, the SAP score, the Environmental Impact band, and the Environmental Impact score, as well as their impact on the SAP-calculated fuel costs, CO2 emissions and delivered energy consumption. These results are set out in Table 1.

Table 1: Modelled Single Improvements: EPC Band, SAP Score, Environmental Impact Band, Environmental Impact Score, SAP Annual Fuel Costs, SAP CO2 emissions, and SAP Delivered Energy Consumption (ordered by impact on the SAP score (lowest to highest))

						SAP Annual Fuel Costs: £ per year						SAP CO2 Emissions: kg of CO2 per year						SAP Delivered Energy Consumption: kWh per year					
code	Improvement Description	EPC	SAP	EI	EIs	MH	SecH	HW	L	ren	tot	MH	SecH	HW	L	ren	tot	MH	SecH	HW	L	ren	tot
Base	as existing	F	30	F	27	£1,073	£312	£153	£120	£0	£1,778	6658	1227	950	473	0	9307	30825	2363	4398	911	0	38497
M12	draughtproof windows and doors	F	30	F	28	£1,066	£310	£153	£120	£0	£1,769	6619	1219	950	473	0	9261	30644	2349	4398	911	0	38302
M7	double glazing to 1.8	F	30	F	28	£1,062	£309	£153	£120	£0	£1,764	6591	1214	950	474	0	9229	30512	2339	4399	913	0	38163
M8	secondary glazing to 2.4	F	30	F	28	£1,063	£309	£153	£120	£0	£1,765	6596	1215	950	474	0	9236	30538	2341	4399	913	0	38192
M11	hot water tank jacket 80mm	F	30	F	28	£1,076	£313	£141	£120	£0	£1,769	6679	1230	873	473	0	9254	30921	2371	4040	911	0	38242
M31	2m diameter wind turbine on roof	F	30	F	28	£1,073	£312	£153	£120	-£19	£1,759	6658	1227	950	473	-74	9233	30825	2363	4398	911	-143	38354
M33	low energy lighting 100%	F	31	F	28	£1,078	£313	£153	£82	£0	£1,746	6691	1233	950	321	0	9195	30979	2375	4398	619	0	38370
M10	insulated external doors	F	31	F	28	£1,053	£306	£153	£120	£0	£1,752	6534	1204	950	473	0	9160	30248	2319	4399	911	0	37877
M29	Solar thermal 4m2	F	31	F	29	£1,074	£312	£92	£127	£0	£1,724	6663	1227	572	499	0	8961	30848	2365	2646	961	0	36821
M9	triple glazing to 1.4	F	31	F	28	£1,042	£303	£153	£123	£0	£1,741	6529	1192	959	485	0	9165	29951	2296	4399	934	0	37580
M13	baffle / damper to open fire	F	31	F	29	£1,036	£301	£153	£120	£0	£1,730	6430	1185	950	473	0	9038	29769	2282	4400	911	0	37361
M4	cavity wall insulation	F	32	F	29	£1,024	£298	£153	£120	£0	£1,715	6355	1171	950	473	0	8949	29422	2256	4400	911	0	36989
M6	floor insulation	F	32	F	29	£1,021	£297	£153	£120	£0	£1,711	6336	1167	950	473	0	8926	29331	2249	4400	911	0	36891
M24	room thermostat	F	32	F	30	£1,000	£312	£142	£115	£0	£1,689	6208	1227	882	454	0	8771	28742	2363	4083	875	0	36063
M5	solid wall insulation	F	34	F	31	£963	£280	£153	£120	£0	£1,636	5978	1101	951	473	0	8503	27675	2122	4403	911	0	35111
M30	PV 2kWp	F	35	F	31	£1,073	£312	£153	£120	-£180	£1,597	6658	1227	950	473	-710	8598	30825	2363	4398	911	-1367	37130
M32	5m wind turbine on stand-alone mast	F	36	F	31	£1,073	£312	£153	£120	-£208	£1,570	6658	1227	950	473	-818	8490	30825	2363	4398	911	-1575	36922
M14	replace gas boiler with condensing boiler 88%	F	37	F	34	£881	£312	£125	£120	£0	£1,558	5469	1227	774	473	0	7943	25320	2363	3585	911	0	32179
M1	loft insulation, including top up	F	40	F	36	£829	£241	£154	£120	£0	£1,463	5143	947	953	473	0	7516	23812	1826	4411	911	0	30959
M3	room in the roof insulation	E	48	E	43	£674	£196	£154	£120	£0	£1,264	4185	771	955	473	0	6384	19374	1485	4423	911	0	26193

EPC = EPC band / SAP = SAP 2012 score / EI = Environmental Impact band / EIs = Environmental Impact score

MH = main heating / SecH secondary heating / HW = hot water / L = lighting and other costs (e.g. fans and pumps) / ren = impact of renewable generation / tot = total of category

The starting point for this dwelling (i.e. as existing) is a Band F SAP score of 30, that is, 9 points short of Band E, and 25 points below Band D.

For this dwelling, 19 improvement measures were assessed. Those that were not assessed, and the reasons, are set out in Table 2.

Table 1 above is ordered in terms of the smallest impact on the increase in the SAP score to the highest. Five measures do not have an impact on the SAP score:

M12 draughtproof windows and doors
M7 double glazing to 1.8
M8 secondary glazing to 2.4
M11 hot water tank jacket 80mm
M31 2m diameter wind turbine on roof

While these 5 measures do improve the dwelling's overall energy efficiency, the improvements are not sufficient in themselves to increase the SAP score by 1 full SAP point.

Two measures on their own (highlighted in yellow in Table 1 above) would raise the SAP rating into the Band E category. Neither of these measures are mutually exclusive.
No assessed measure on its own would raise the SAP rating into Band D or higher.

Note: In SAP and RdSAP, the estimated delivered energy (which is assumed to be electricity) generated from a installed photovoltaic system (PVs) and / or a wind turbine is converted to a monetary value, a carbon dioxide emission equivalent value, and a primary energy value using conversion factors from Table 12 of the SAP manual. These amounts are then subtracted from the respective estimated delivered energy, SAP fuel cost, carbon dioxide emission equivalent, and primary energy totals of the dwelling without the PVs and / or wind turbine. The impact of the installation of photovoltaics and / or wind turbines appears in the 'ren' columns in above table as a negative number.

Table 2: Reasons for Measures Not Assessed in this Property

code	Improvement Description	Improvement Modelled?
M2	flat roof insulation	not applicable
M15	replace oil boiler with condensing boiler 90%	not applicable
M16	full gas central heating system inc controls	not recommended
M17	full oil central heating system inc controls	not recommended
M18	full biomass central heating system inc controls	not recommended
M19	fan electric storage heaters with auto charge control	not recommended
M20	quantum storage heaters	not recommended
M21	full electric radiator system inc controls - off peak tariff	not recommended
M22	air source heat pump	not recommended
M23	ground source heat pump	not recommended
M25	programmer for heating system	already present
M26	TRVs	already present
M27	full controls package (r/stat, programmer and TRVs)	not recommended
M28	Auto charge control	not applicable
M34	Cylinder stat for hot water cylinder	not applicable
M35	Air to Air heat pump	not recommended
M36	replace secondary heating with one more efficient	not recommended
M37	electric CPSU with raidtors and controls on E18 tariff	not recommended
M38	switch to E24 tariff	not applicable

A number of the improvement measures were not assessed with regard to this dwelling. Appendix 2 of the Final Report sets out the methodology associated with modelling the 38 improvements, including why measures were not recommended, or not applicable.

Table 3: Impact of Single Improvements on Annual and Lifetime SAP Fuel Costs, CO2 emissions, Delivered Energy Consumption - ordered by Capital Costs (lowest to highest)

						annual reductions				lifetime reductions							
code	Improvement Description	EPC Band	Change in SAP score	EI Band	Change in EI score	SAP £/year	SAP kg CO2/year	SAP delivered kWh/year	lifetime (years)	SAP £	SAP kg CO2	SAP delivered kWh	unit costs	units	capital cost	net lifetime £ saving / capital cost	payback (years)
M11	hot water tank jacket 80mm	F	0	F	1	8	53	255	10	82	529	2554	£23	1	£23	£2.64	2.8
M33	low energy lighting 100%	F	1	F	1	32	112	127	5	158	562	634	£5	7	£35	£3.52	1.1
M12	draughtproof windows and doors	F	0	F	1	8	46	195	10	81	463	1949	£100	1	£100	-£0.19	12.3
M13	baffle / damper to open fire	F	1	F	2	47	270	1135	42	1990	11332	47691	£50	3	£150	£12.27	3.2
M24	room thermostat	F	2	F	3	88	537	2434	12	1058	6439	29205	£200	1	£200	£4.29	2.3
M1	loft insulation, including top up	F	10	F	9	315	1791	7538	42	13211	75229	316600	£350	1	£350	£36.74	1.1
M4	cavity wall insulation	F	2	F	2	63	358	1508	42	2643	15050	63340	£1,000	1	£1,000	£1.64	15.9
M6	floor insulation	F	2	F	2	67	382	1606	42	2814	16027	67451	£1,000	1	£1,000	£1.81	14.9
M10	insulated external doors	F	1	F	1	26	147	620	30	776	4418	18595	£500	2	£1,000	-£0.22	38.7
M8	secondary glazing to 2.4	F	0	F	1	13	72	305	20	250	1436	6104	£1,250	1	£1,250	-£0.80	100.0
M3	room in the roof insulation	E	18	E	16	513	2924	12304	42	21563	122790	516750	£2,100	1	£2,100	£9.27	4.1
M14	replace gas boiler with condensing boiler 88%	F	7	F	7	220	1365	6318	12	2638	16376	75813	£2,600	1	£2,600	£0.01	11.8
M31	2m diameter wind turbine on roof	F	0	F	1	19	74	143	10	189	743	1431	£2,750	1	£2,750	-£0.93	145.7
M7	double glazing to 1.8	F	0	F	1	14	79	334	20	274	1573	6682	£4,900	1	£4,900	-£0.94	357.4
M29	Solar thermal 4m2	F	1	F	2	53	346	1676	25	1333	8660	41908	£5,000	1	£5,000	-£0.73	93.8
M9	triple glazing to 1.4	F	1	F	1	36	142	917	20	722	2849	18331	£7,500	1	£7,500	-£0.90	207.6
M5	solid wall insulation	F	4	F	4	141	805	3386	36	5086	28966	121905	£9,000	1	£9,000	-£0.43	63.7
M30	PV 2kWp	F	5	F	4	180	710	1367	25	4508	17739	34178	£11,500	1	£11,500	-£0.61	63.8
M32	5m wind turbine on stand-alone mast	F	6	F	4	208	818	1575	10	2078	8176	15753	£20,000	1	£20,000	-£0.90	96.3

nb. because of the rounding of the annual reductions to the nearest integer, some of the lifetime reductions may not equal a measure's annual reduction multiplied by its respective lifetime

- because this measure has no impact on the SAP-calculated fuel bill no payback period can be calculated.

Table 3 sets out the resultant EPC and Environmental Impact (EI) banding for each of the individual improvement measures assessed for this dwelling, along with the changes in the respective SAP and EI scores. It then displays the impact on the respective SAP-calculated annual fuel bill, CO2 emissions and delivered energy consumption for the dwelling (the pink columns in Table 3 above). Multipling the annual change in the calculated SAP fuel costs, CO2 emissions, and delivered energy consumption for this property, by the respective lifetime of each of the measures assessed, produces the lifetime change for each measure (see the blue columns in Table 3 above). This allows us to compare the capital costs against both the cost of the saving on the fuel bill on an annual basis (i.e. the payback), and over the lifetime of the measure (i.e. the net lifetime £ saving / capital cost). The net lifetime £ saving / capital cost subtracts the capital cost of the measure from the calculated lifetime SAP £ reduction. In this column, a value greater than 0 here means the calculated lifetime fuel bill savings are greater than the capital cost of installing the measure. Where the net lifetime saving is a negative number, that is, it has a cost effectiveness of less than 0 (and highlighted in orange in Table 3), the measure will not return the cost of the original investment through savings in the fuel bills alone.

Table 3 is ordered from the lowest capital cost for the improvement measure assessed to the highest. The capital costs of the individual measures ranged from £23 for a hot water tank jacket, up to £20,000 for the stand-alone wind turbine. A low capital cost does not necessarily equate to a good return on an investment or short payback period; similarly, a high capital cost does not necessarily mean a poor return on the cost of the investment or a long payback. In terms of cost effectiveness, the two measures with the shortest payback for this archetype are installing low energy lighting throughout the dwelling, and loft inulation, both with a payback of 1.1 years. Installing loft insulation has a longer payback period, but provides the largest lifetime return on the cost of the improvement, with a return of £36.74 for every pound invested over the lifetime of the measure.

Ten of the measures have a cost effectiveness of less than 0 (highlighted in orange in Table 3) and will not return the cost of the original investment through savings in the fuel bills alone. However, the eligibility for other incentive schemes (e.g. Feed in Tariffs for fitting PV systems and wind turbines, and the Renewable Heat Incentive for fitting solar thermal systems) are likely to have a significant impact on the financial return associated with these measures. The financial benefits associated with these incentive schemes are not included in the calculations here, because of their constantly changing returns.

From the characteristics of this archetype, the starting point for this dwelling was assessed to be a RdSAP 2012 Band F SAP score of 30. Two separate packages were assessed for this archetype: the cheapest package of measures to raise the SAP score so that it achieved a SAP Band E score of at least 39; and, the cheapest package of measures to raise the SAP score so that it achieved a SAP Band D score of at least 55. While some measures may be common to all of the packages, each package was assessed independently of one another, so that the separate packages for this dwelling may have no components in common.

Table 4a: Cheapest Package of improvement Measures to Increase the SAP EPC Band to SAP Band E

						cummulative annual reductions				cummulative lifetime reductions							
code	Improvement Description	EPC Band	SAP	EI Band	EI score	SAP £/year	SAP kg CO2/year	SAP delivered kWh/year	lifetime (years)	SAP £	SAP kg CO2	SAP delivered kWh	unit costs	units	cummulative capital cost	cummulative net lifetime £ saving / capital cost	cummulative payback (years)
Base	as existing	F	30	F	27												
M1	loft insulation, including top up	E	40	F	36	315	1791	7538	42	13211	75229	316600	£350	1	£350	36.74	1.1

Installing loft insulation in this property was assessed as the cheapest way to move the SAP rating for this property into Band E (see Table 4a). The indicative cost was estimated at £350.

Table 4b: Cheapest Package of improvement Measures to Increase the SAP EPC Band to SAP Band D

						cummulative annual reductions				cummulative lifetime reductions							
code	Improvement Description	EPC Band	SAP	EI Band	EI score	SAP £/year	SAP kg CO2/year	SAP delivered kWh/year	lifetime (years)	SAP £	SAP kg CO2	SAP delivered kWh	unit costs	units	cummulative capital cost	cummulative net lifetime £ saving / capital cost	cummulative payback (years)
Base	as existing	F	30	F	27												
M3	room in the roof insulation	E	48	E	43	523	2977	12530	42	21960	125049	526253	£2,100	1	£2,100	9.46	4.0
M3+M14	+ replace gas boiler with condensing boiler 88%	E	54	E	50	671	3894	16773	12	23732	136047	577168	£2,600	1	£4,700	4.05	7.0
M3+M14+M11	+ hot water tank jacket 80mm	D	55	E	50	677	3935	16975	10	23794	136459	579186	£23	1	£4,723	4.04	7.0

No single measure was assessed to achieve the Band D for this dwelling, therefore a package of measures was assessed. Installing room in the roof insulation in conjunction with insulating the rest of the loft space, replacing the existing boiler with a more efficient condensing model with an efficiency of at least 88%, and fitting an additional jacket on the hot water cylinder in this property was assessed as the cheapest way to move the SAP rating for this property into Band D (see Table 4b). The total indicative cost of this package was estimated at approximately £4,723.

5 IMPROVING THE TARGET STOCK

5.1 Following discussion among the REEPS Research Advisory Group and REEPS members, it was agreed that 4 policy scenarios should be modelled:

- Scenario 1: All dwellings to reach EPC band F (improve dwellings in EPC band G to reach minimum threshold of Band F).
- Scenario 2: All dwellings to reach EPC band E (improve dwellings in EPC bands G and F to reach minimum threshold of Band E).
- Scenario 3: All dwellings to reach EPC band D (improve dwellings in EPC bands G, F and E to reach minimum threshold of Band D).
- Scenario 4: All dwellings to move up one EPC band.

5.2 This chapter briefly summarises the potential impact of the 38 improvement measures individually before detailing the scope and impact of the 4 different policy scenarios.

Summary of individual measures

5.3 Table 5.1 shows the status of all 38 individual measures across the REEPS target stock. As noted in Chapter 4, individual measures were modelled for all dwellings where it was possible to implement and where they would potentially increase the SAP rating. Measures that were modelled in at least 50% of dwelling were:

- Insulated External Doors (99%)
- Low energy lighting to 100% (89%)
- 2m diameter wind turbine on roof (86%)
- Floor insulation (86%)
- 5m wind turbine on stand-alone mast (81%)
- Draught proofing windows and doors (79%)
- Triple glazing to a U-value of at least 1.4 W/m^2K (79%)
- Loft insulation including top-up (75%)
- PV 2Kwp (64%)
- Solar thermal $4m^2$ (62%)
- Solid wall insulation (57%)
- and Hot water tank jacket of 80mm (54%).

5.4 The measures most commonly already present were:

- Double glazing to 1.8 W/m^2K (71%)
- Programmer for heating system (67%)

- Thermostatic radiator valves (TRVs - 54%)
- Cylinder stat for hot water cylinder (45%)
- Room thermostats (31%).

Table 5.1: Summary of status[57] of individual measures across all of the target stock

	Already present	Modelled	Not appropriate	Not recommended	Total	Modelled (n)
M10: Insulated External Doors	0%	99%	0%	1%	100%	397,356
M33: Low Energy Lighting 100%	11%	89%	0%	0%	100%	356,043
M31: 2M Diameter Wind Turbine On Roof	0%	86%	0%	14%	100%	346,307
M6: Floor Insulation	1%	86%	13%	0%	100%	344,772
M32: 5M Wind Turbine On Stand-Alone Mast	0%	81%	0%	19%	100%	326,251
M12: Draughtproof Windows And Doors	21%	79%	0%	0%	100%	316,074
M9: Triple Glazing To 1.4	1%	79%	0%	20%	100%	314,738
M1: Loft Insulation, Including Top Up	14%	75%	10%	0%	100%	300,669
M30: Pv 2Kwp	0%	64%	0%	36%	100%	255,674
M29: Solar Thermal 4M2	0%	62%	0%	38%	100%	246,667
M5: Solid Wall Insulation	1%	57%	41%	1%	100%	229,762
M11: Hot Water Tank Jacket 80Mm	17%	54%	28%	1%	100%	216,082
M13: Baffle / Damper To Open Fire	2%	46%	52%	0%	100%	182,296
M4: Cavity Wall Insulation	0%	45%	53%	2%	100%	181,708
M24: Room Thermostat	31%	37%	31%	2%	100%	147,386
M14: Replace Gas Boiler With Condensing Boiler 88%	6%	35%	58%	1%	100%	141,859
M20: Quantum Storage Heaters	0%	30%	0%	70%	100%	119,434
M3: Room In The Roof Insulation	1%	29%	70%	0%	100%	118,072
M19: Fan Elec Storage Heaters With Auto Charge Control	1%	29%	0%	71%	100%	115,201
M35: Air To Air Heat Pump	0%	28%	1%	71%	100%	110,963
M7: Double Glazing To 1.8	71%	26%	0%	3%	100%	103,520
M8: Secondary Glazing To 2.4	1%	25%	1%	73%	100%	99,270
M36: Replace Secondary Heating with more efficient one	0%	24%	9%	67%	100%	96,558
M15: Replace Oil/LPG Boiler to 90%	4%	18%	71%	8%	100%	71,515
M34: Cylinder Stat For Hot Water Cylinder	45%	14%	41%	0%	100%	57,247

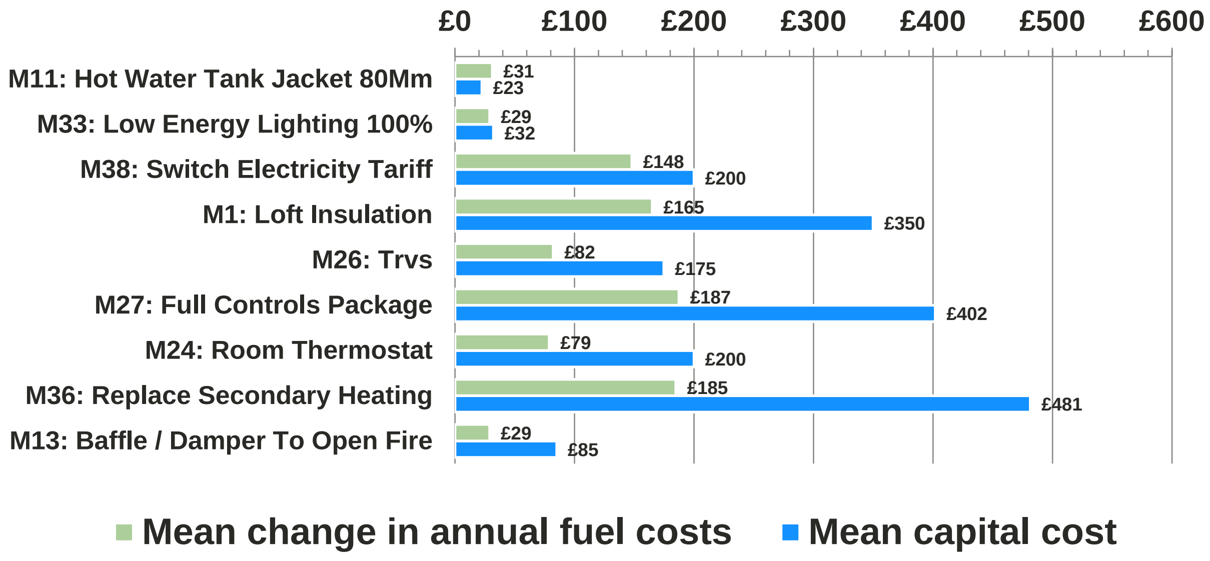
[57] Appendix 2 provides full details of how the status of each measure was defined.

	Already present	Modelled	Not appropriate	Not recommended	Total	Modelled (n)
M26: Trvs	54%	14%	32%	0%	100%	57,100
M2: Flat Roof Insulation	0%	12%	88%	0%	100%	46,617
M38: Switch Electricity Tariff	1%	10%	68%	22%	100%	38,714
M28: Auto Charge Control	11%	7%	72%	9%	100%	29,631
M27: Full Controls Package	21%	4%	31%	44%	100%	15,705
M18: Full Biomass Central Heating System Inc Controls	0%	4%	0%	96%	100%	14,979
M16: Full Gas Central Heating System Inc Controls	0%	4%	1%	95%	100%	14,374
M22: Air Source Heat Pump	0%	3%	0%	97%	100%	10,886
M23: Ground Source Heat Pump	0%	3%	0%	97%	100%	10,800
M17: Full Oil/LPG Central Heating System Inc Controls	0%	2%	1%	97%	100%	8,273
M25: Programmer For Heating System	67%	2%	31%	1%	100%	6,201
M21: Full Elec Radiator System Inc Controls - Off Peak	0%	1%	0%	99%	100%	2,412
M37: Elec CPSU With Radiators And Controls On E18 Tariff	0%	0.5%	1%	99%	100%	1,941

5.5 The number of measures modelled by rurality, tenure and EPC banding is provided in Table A8.5 in Appendix 8.

5.6 Nine individual measures had a payback period of less than three years. These are shown in Figure 5.1.

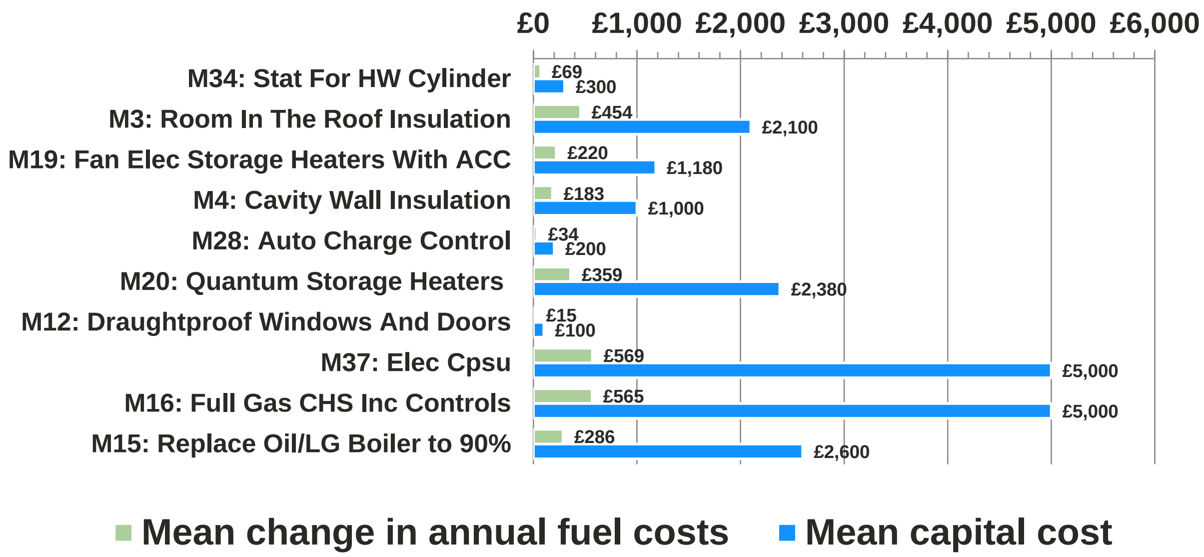
Figure 5.1: Mean capital cost and annual reduction in energy costs of the nine measures with a payback period less than three years.



5.7 In terms of their impact on SAP scores and their potential scope among the target stock (Table A8.6):

- Adding a hot water tank jacket of 80mm increased the SAP score on average by 1.2 points and was modelled in 216,082 dwellings (54%).
- Low energy lighting increased the SAP score on average by 1.0 point and was modelled in 356,043 dwellings (89%).
- Switching electricity tariff raised the SAP score by 5.6 points on average and was modelled in 38,714 (10%) dwellings.
- Loft insulation, including top-up insulation increased the SAP score by 5.3 points on average and was modelled in 300,669 dwellings (75%).
- TRVs increased the SAP rating by 2.4 points on average and were modelled in 57,100 dwellings (14%).
- Full Control Package increased the SAP score by 4.1 points on average and was modelled in 15,705 dwellings (4%).
- Room thermostats increased the SAP score by 2.4 points on average and were modelled in 147,386 dwellings (37%).
- Replacing the secondary heating increased the SAP score by 5.2 points on average was modelled in 96,558 dwellings (24%).
- Adding a baffle/damper to an open fire increased the SAP score by 0.9 points on average and was modelled in 181,708 dwellings (45%).

Figure 5.2: Mean capital cost and annual reduction in energy costs of the ten improvement measures with an average payback period of between three and ten years.



5.8 Ten individual measures had a payback period of between three and ten years (shown in Figure 5.2).

- Adding a cylinder stat for hot water cylinder increased the SAP score on average by 2.1 points and was modelled in 57,247 dwellings (14%) and
- Room in the roof insulation increased the SAP score on average by 13.0 points and was modelled in 118,072 dwellings (29%).
- Fan electric storage heaters with auto charge control increased the SAP score on average by 8.3 points and was modelled in 115,201 dwellings (29%).
- Cavity Wall Insulation increased the SAP score on average by 6.6 points and was modelled in 182,296 dwellings (46%).
- Auto charge control increased the SAP score on average by 1.2 points and was modelled in 29,631 dwellings (7%).
- Adding Quantum storage heaters increased the SAP score on average by 14.0 points and was modelled in 119,434 dwellings (30%).
- Draught proofing windows and doors increased the SAP score on average by 0.5 points and was modelled in 316,074 dwellings (79%).
- Adding an electric Combined Primary Storage Unit (CPSU) system with radiators and controls on E18 tariff increased the SAP score on average by 17.0 points and was but modelled in 1,941 dwellings (< 0.5%).
- Adding full gas central heating system including controls increased the SAP score on average by 26.2 points and was modelled in 14,374 dwellings (4%).
- Replacing an Oil/LG boiler with one that was 90% efficient increased the SAP score on average by 7.4 points and was modelled in 71,515 dwellings (18%).

5.9 The remaining 19 measures all had a payback period of more than ten years. Summary information on all 38 individual measures, including the average payback period, mean change in SAP, annual fuel costs, CO_{2e}, Primary Energy, Delivered Energy[58], and average capital costs are shown in Table A8.6 in Appendix 8.

Measures included in different scenarios

5.10 Table 5.2 shows the measures included in the improvement packages for each of the Scenarios. The most common measures included were loft insulation (including top-up loft insulation), room thermostats, low energy lighting, hot water tank jackets and cavity wall insulation. For Scenario 1, the most common measures were:

[58] Primary energy consumption includes losses that occur in the generation, transmission and delivery of energy before reaching dwellings. Delivered energy consumption only takes account of energy used from the point that it reaches the dwelling.

- Adding loft insulation (62% of target stock: 18,375 dwellings)
- Hot Water tank jacket (16% of target stock: 4,651 dwellings)
- Room thermostats (15% of target stock: 4,457 dwellings)
- Fan electric storage heaters with auto-charge control (10% of target stock: 2,878 dwellings)
- Replacing secondary heating system (9% of target stock: 2,537 dwellings).

5.11 For Scenario 2, the most common measures were:

- Adding loft insulation (44% of target stock: 74,369 dwellings)
- Low energy lighting (15% of target stock: 25,496 dwellings)
- Cavity wall insulation (14% of target stock: 24,611 dwellings)
- Hot Water tank jacket (13% of target stock: 21,783 dwellings)
- Replacing secondary heating system (13%: 21,700 dwellings).

5.12 For Scenario 3, the most common measures were:

- Adding loft insulation (39% of target stock: 157,256 dwellings)
- Low energy lighting (34% of target stock: 135,662 dwellings)
- Cavity wall insulation (26% of target stock: 103,250 dwellings)
- Hot Water tank jacket (22% of target stock: 88,179 dwellings)
- Floor insulation (22% of target stock: 87,806 dwellings)
- Replacing secondary heating system (18% of target stock: 70,274 dwellings)
- Room thermostats (15% of target stock: 58,363).

5.13 For Scenario 4, the most common measures were:

- Adding loft insulation (33% of target stock: 133,380 dwellings)
- Low energy lighting (25% of target stock: 101,310 dwellings)
- Hot Water tank jacket (16% of target stock: 62,406 dwellings)
- Cavity wall insulation (16% of target stock: 63,849 dwellings)
- Room thermostats (10% of target stock: 41,752 dwellings)
- Replacing secondary heating system (10% of target stock: 38,212 dwellings).

Table 5.2: Individual measures included in packages (counts and %age of dwellings where measure included. Improvements that were not recommended in any dwelling in any scenario are not shown).

	Scenario 1 - Reach Band F		Scenario 2 - Reach Band E		Scenario 3 - Reach Band D		Scenario 4 - One band up	
	%age	Total	%age	Total	%age	Total	%age	Total
Base (Total dwellings improved)		**29,676**		**170,708**		**400,548**		**400,548**
M1: Loft Insulation, inc' top up	62%	18,375	44%	74,369	39%	157,256	33%	133,380
M2: Flat Roof Insulation	0%	0	1%	1,579	2%	7,359	1%	4,057
M3: Room In The Roof Insulation	0%	0	10%	16,815	18%	71,075	5%	18,722
M4: Cavity Wall Insulation	9%	2,649	14%	24,611	26%	103,250	16%	63,849
M5: Solid Wall Insulation	0%	0	1%	1,181	7%	29,561	1%	3,538
M6: Floor Insulation	5%	1,632	5%	9,262	22%	87,806	9%	34,983
M7: Double Glazing To 1.8	0%	0	0%	0	1%	2,701	0%	0
M8: Secondary Glazing To 2.4	0%	0	0%	438	2%	6,504	1%	2,248
M10: Insulated External Doors	0%	0	1%	1,604	3%	11,196	2%	6,515
M11: HW Tank Jacket 80Mm	16%	4,651	13%	21,783	22%	88,179	16%	62,406
M12: Draught proof windows & doors	0%	0	4%	7,492	5%	20,275	3%	13,619
M13: Baffle/Damper To Open Fire	0%	0	3%	5,412	6%	22,214	5%	19,169
M14: Replace Gas Boiler With Condensing Boiler 88%	0%	0	3%	4,519	6%	25,928	3%	12,650
M15: Replace Oil/LPG Boiler to 90%	3%	1,002	6%	10,046	7%	28,566	2%	9,730
M16: Full Gas CH Sys Inc Controls	0%	0	0%	0	0%	1,704	0%	0
M17: Full Oil/LPG CH Sys Inc Controls	0%	76	1%	1,802	1%	5,312	0%	779
M18: Full Biomass CH Inc Controls	0%	0	0%	41	0%	41	0%	0
M19: Fan Elec Storage Heaters With Auto Charge Control	10%	2,878	10%	16,541	5%	19,211	4%	15,342
M20: Quantum Storage Heaters	0%	0	4%	7,680	10%	39,291	3%	13,684
M24: Room Thermostat	15%	4,457	8%	12,998	15%	58,363	10%	41,752
M26: TRVs	4%	1,124	2%	2,980	6%	24,864	5%	18,371
M27: Full Controls Package	0%	0	2%	3,526	1%	4,817	1%	2,994
M28: Auto Charge Control	0%	0	1%	2,024	1%	4,939	2%	6,447
M29: Solar Thermal 4m^2	0%	0	0%	0	1%	3,345	0%	0
M31: 2m Wind Turbine on roof	0%	0	0%	0	0%	1,287	0%	1,287
M33: Low Energy Lighting 100%	3%	949	15%	25,496	34%	135,662	25%	101,310
M34: Cylinder Stat For HW Cylinder	2%	708	2%	2,791	4%	17,288	3%	10,051
M36: Replace Secondary Heating system	9%	2,537	13%	21,700	18%	70,274	10%	38,212
M38: Switch Electricity Tariff	2%	611	2%	2,878	3%	13,399	4%	16,038

5.14 There were some differences by rurality, particularly in relation to Scenario 3. This primarily reflects differences in the characteristics of the stock in rural areas, and in particular, the average unimproved position (discussed further below) and the main heating system.

5.15 A higher proportion of dwellings in rural areas than in urban areas have the following measures included in Scenario 3: room in the roof insulation. (28% compared to 10%), floor insulation (40% compared to 9%), and the replacement Oil/LPG Boilers to one with 90% efficiency (16% compared to 1%). (See Table A8.9 in Appendix 8). In contrast, dwellings in urban areas are more likely those in rural areas to have low energy lighting (36% compared to 30%) in Scenario 3.

5.16 In comparison, there was very little difference in the measures included in the packages by tenure. (See Table A8.7)

The four different policy scenarios

5.17 Table 5.3 summarises the key information for the different policy scenarios.

Table 5.3: Summary of key indicators for the different policy scenarios

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
	All dwellings to Band F	**All dwellings to Band E**	**All dwellings to Band D**	**ALL EFG to improve one band**
Number of dwellings improved	29,676	170,708	400,548	400,548
Mean SAP score pre improvement	12.3	28.5	39.4	39.4
Mean SAP score increase	13.7	13.4	16.4	9.4
Mean EI score pre improvements	24.1	24.6	32.4	32.4
Mean EI score increase	7.6	7.6	11.9	6.9
Mean capital cost of improvements	£627	£1,232	£2,672	£969
Overall capital cost of improvements	£18.6 m	£210.2 m	£1070.2 m	£388.1 m
Banded capital cost: %age (n) £0-£200	13% (3,936)	13% (21,341)	17% (68,078)	23% (93,335)
Banded capital cost: %age (n) £201-£500	52% (15,396)	35% (59,970)	13% (52,689)	30% (121,333)
Banded capital cost: %age (n) £501-£1,000	20% (6,000)	15% (25,102)	8% (30,187)	14% (57,087)
Banded capital cost: %age (n) £1,001-£2,000	11% (3,266)	12% (20,517)	16% (62,725)	16% (66,046)
Banded capital cost: %age (n) £2,001-£5,000	3% (1,002)	24% (41,145)	33% (133,000)	15% (58,174)
Banded capital cost: %age (n) £5,001-£10,000	0% (76)	1% (2,160)	7% (29,113)	1% (4,553)
Banded capital cost: %age (n) >£10,000	0% (0)	0% (473)	6% (24,756)	0%(0)
Mean fuel cost pre improvement (£ per annum)	£2,464	£2,062	£1,642	£1,642
Mean reduction in fuel costs (£ per annum)	£542	£463	£483	£279
Overall fuel cost pre improvement (per annum)	£73.1 m	£352.0 m	£657.8 m	£657.8 m
Overall reduction in fuel costs (per annum)	£16.1 m	£79.0 m	£193.0 m	£111.6 m
Mean CO_{2e} consumed pre improve' (kg per annum)	11,197	11,604	9,319	9,319
Mean reduction in CO_{2e} consumed (kg per annum)	2,113	2,119 kg	2,617 kg	1,515 kg
Overall CO_{2e} consumed pre improvement (thou tons)	332k tons	1,981k tons	3,733k tons	3,733k tons
Overall reduction in CO_{2e} (thousand tons per annum)	62.7k tons m	361.7k tons	1,046k tons	605.8k tons

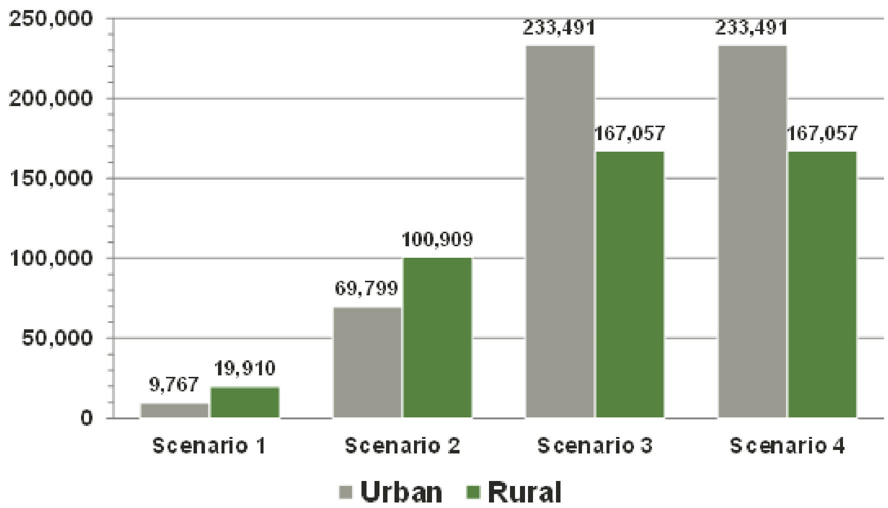
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	All dwellings to Band F	**All dwellings to Band E**	**All dwellings to Band D**	**ALL EFG to improve one band**
Mean Primary Energy consumed pre (kWh pa)	55,695	56,117	46,734	46,734
Mean reduction in PE (kWh per annum)	10,313	9,894	12,583	7,424
Overall PE consumed before package (kWh pa)	1,653 m	9,580 m	18,719 m	18,719 m
Overall reduction in PE (kWH pa)	306 m	1,689 m	5,030 m	2,968 m
Mean Delivered Energy consumed pre (kWH pa)	36,447	37,532	31,104	31,104
Mean reduction in DE (kWh per annum)	6,885	7,460	8,927	5,114
Overall DE consumed before package (kWH pa)	1,082 m	6,407 m	12,459 m	12,459 m
Overall reduction in DE (kWh pa)	204 m	1,273 m	3,569 m	2,044 m
Median payback period	1.1	2.3	3.8	2.5
Mean payback period	1.2	2.7	5.5	3.5
Mean capital cost per SAP point increase	£46	£92	£163	£103

5.18 By definition, Scenario 1 (improving all dwellings to reach EPC band F) and Scenario 2 (all dwellings to reach EPC band E) would involve upgrading fewer dwellings than Scenarios 3 and 4 (all dwellings to reach D and all target dwellings to move up one banding).

- 29,676 dwellings would be improved by Scenario 1
- 170,708 dwelling would be improved by Scenario 2
- 400,548 dwellings would be improved by Scenarios 3 and 4.

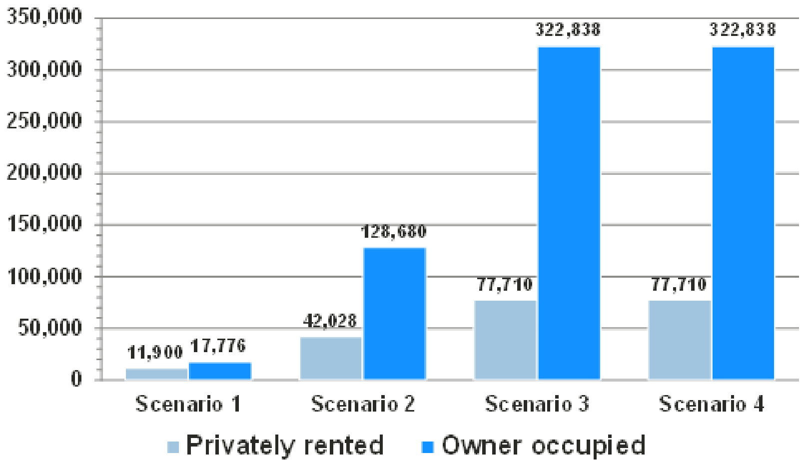
5.19 While 42% of the overall REEPS target stock is in rural areas, the proportion varies by EPC band (Figure 5.3). This has an impact on the urban/rural split covered by the different scenarios. The majority of dwellings affected by Scenarios 1 and 2 would be in rural areas (67% and 59% respectively). In comparison, 42% of dwellings affected by Scenarios 3 and 4 would be in rural areas.

Figure 5.3: Number of dwellings affected by each scenario by urban/rural split



5.20 With regard to tenure, while 19% of the REEPS target stock is privately rented, a higher proportion of dwellings in the two lowest EPC bands, G & F, are privately rented. This affects the tenure split of stock targeted by the different scenarios (Figure 5.4). While 19% of the dwellings affected by Scenarios 3 and 4 are privately rented, 25% of those affected by Scenario 2 and 40% of those affected by Scenario 1 are privately rented.

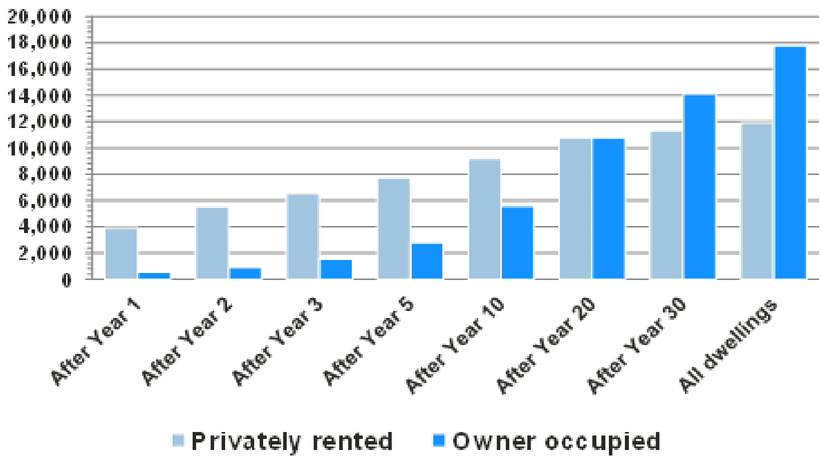
Figure 5.4: Number of dwellings affected by each scenario by tenure



5.21 However, the turnover rate in the private rented sector is considerably higher than in the owner occupied sector[59]. For example, the turnover rate within 5 years among the REEPS target stock is 71% in the private rented sector, compared to 16% for owner occupied dwellings.

5.22 This has a large impact on the tenure make-up of dwellings affected by REEPS for all scenarios as illustrated in Figures 5.5, 5.6 and 5.7[60]. This is important as the implementation of regulations is likely to be closely linked to re-letting rental properties and sale of owner occupied dwellings.

Figure 5.5: Progress towards Scenario 1 based on estimated turnover rates by tenure.



[59] Appendix 10 provides details of the work undertaken by the Scottish Government to estimate turnover rates in the target stock.
[60] Table A8.10 to A8.13 provide further details.

5.23 The private rented sector will make up the vast majority of dwellings affected in the first few years of REEPS, for all scenarios. After three years, private rented dwellings would account for:

- 81% of the 8,104 dwellings affected by Scenario 1
- 67% of the 34,353 dwellings affected by Scenario 2
- 62% of the 75,908 dwellings affected by Scenarios 3 & 4.

5.24 It would be a considerable length of time before the number of dwellings in the owner occupied sector would match those affected in the private rented sector: around 20 years for Scenario 1; between 5 and 10 years for Scenario 2; and around 5 years for Scenarios 3 and 4.

Figure 5.6: Progress towards Scenario 2 based on estimated turnover rates by tenure.

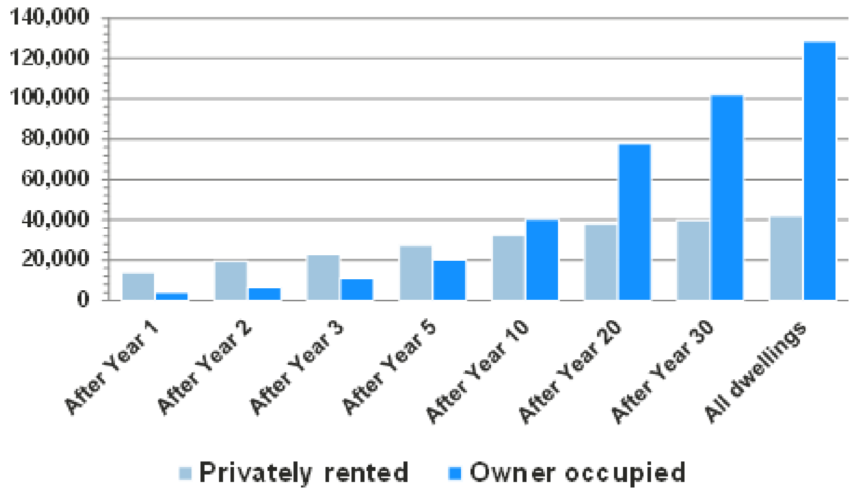
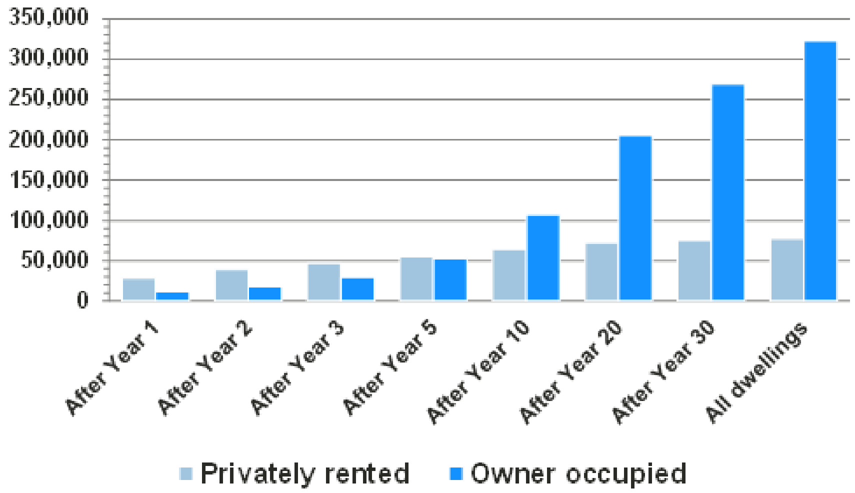


Figure 5.7: Progress towards Scenarios 3 and 4 based on estimated turnover rates by tenure.



Capital costs

5.25 The number of dwellings to be improved and the average capital cost of the improvements per dwelling drive the overall capital cost of each scenario.

- Scenario 1 would require £18.6 million
- Scenario 2 would require £210.2 million
- Scenario 3 would require £1,070 million
- Scenario 4 would require £388.1 million (Table 5.3).

5.26 The average capital cost of improvements reflects both how much each dwelling needs to be improved and the base position of the dwelling. Obviously, improvements that make a large increase in energy efficiency are, on average, more expensive than those that make a small increase.

5.27 The average cost of improving a dwelling in EPC band G up one band (to F) would be £627 (Table 5.4). In comparison, to reach band E from band G would on average cost £2,863 and £8,430 to reach band D.

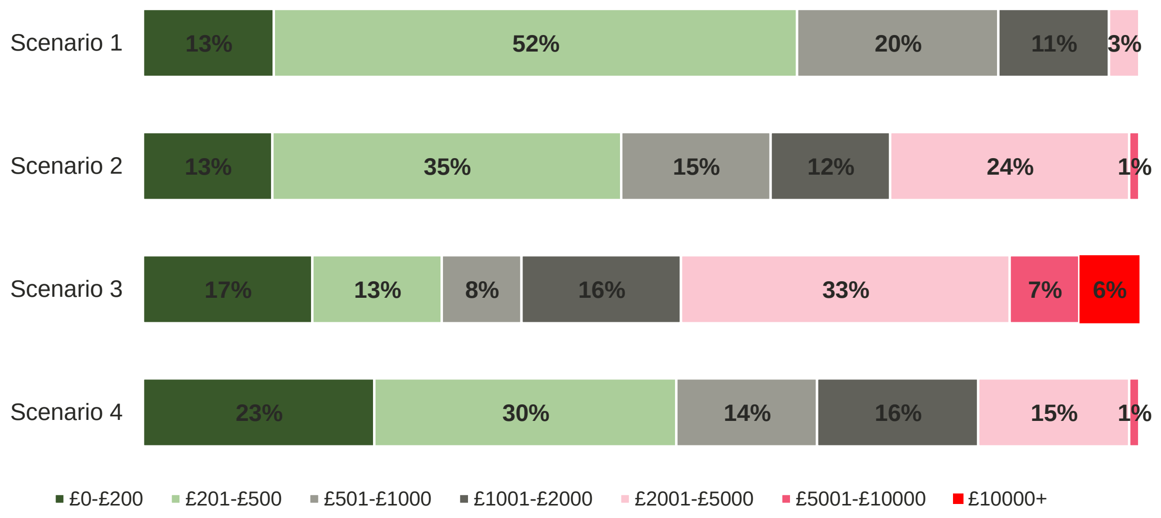
5.28 Moreover, more efficient dwellings are more expensive to improve. The average cost of improving a dwelling in EPC band G by one band is £627. For dwellings in EPC band F, the corresponding figure is £888, while for those in EPC band E, the average cost of improving a dwelling by one band increases to £1,062.

Table 5.4: Average capital cost per dwelling by base position

	EPC banding before improvements			
	G	**F**	**E**	**All target dwellings**
Scenario 1 – To F	£627			£627
Scenario 2 – To E	£2,863	£888		£1,232
Scenario 3 – To D	£8,430	£4,083	£1,062	£2,672
Scenario 4 – 1 Up	£627	£888	£1,062	£969

5.29 This is also reflected in the cost per SAP point increase (£46 per SAP point for dwellings moving from G to F, £88 for dwellings moving from F to E, and £126 for dwellings moving from E to D).

Figure 5.8: Banded capital costs to reach each scenario.



5.30 The average cost of investment for Scenario 1 would be £627 per dwelling:

- 3,936 (13%) would need investment of up to £200 (Figure 5.8)
- 15,396 (52%) would need investment of between £201 and £500
- 9,266 (31%) would need investment between £500 and £2,000
- 1,078 (3%) would need to invest more than £2,000

5.31 The average cost of investment for Scenario 2 would be £1,232 per dwelling

- 21,341 (13%) would need investment of up to £200
- 59,970 (35%) would need investment of between £201 and £500
- 45,619 (27%) would need investment between £500 and £2,000
- 43,778 (25%) would need to invest more than £2,000

5.32 The average cost of investment for Scenario 3 would be £2,672 per dwelling

- 120,767 (30%) would need investment of up to £500
- 92,912 (24%) would need investment of £500 to £2,000
- 133,000 (33%) would need investment of £2,001 to £5,000
- 53,869 (13%) would need investment of more than £5,000

5.33 The average cost of investment for Scenario 4 would be £969 per dwelling:

- 92,335 (23%) would need investment of up to £200
- 122,333 (30%) would need investment of between £201 and £500
- 123,133 (30%) would need investment between £500 and £2,000
- 62,727 (16%) would need to invest more than £2,000

5.34 The average cost of improvements tends to be higher for dwellings in rural areas than dwellings in urban areas across all Scenarios. This difference is most marked for Scenario 3 (£4,092 compared to £1,656 - see Table A8.14 in Appendix 8). This is mainly because of the higher proportion of rural dwellings in EPC bands G and F. However, there is also a difference in the average capital costs of improvement for Scenario 4. The average cost is £1,166 for dwelling in rural areas, compared to £828 in urban areas. There is no clear difference in the average costs of improvements between Owner-Occupied stock and Private Rented Stock (Table A8.).

Impact of the different scenarios

5.35 Broadly, the overall impacts of the different scenarios follow a similar pattern to costs.

5.36 In terms of overall savings in relation to fuel costs, CO_{2e} emissions and Primary and Delivered Energy consumption, Scenario 1 has the smallest impact and Scenario 3 has the largest impact due to the difference in terms of number of dwellings improved and scale of the improvements required. Generally, however, the more efficient a dwelling is pre-improvement, the smaller the impact of measures will be. This means that the average impact on each dwelling tends to be largest where the base position of the stock is the lowest.

Impact on fuel costs

5.37 The overall impact with regard to annual fuel cost savings of the different scenarios would be:

- Scenario 1 would give an annual fuel cost savings of £16.1million (a 22% decrease among dwellings improved).
- Scenario 2, £79.0 million (a 22% decrease)
- Scenario 3, £193.0 million (a 29% decrease)
- Scenario 4, £111.6 million (a 17% decrease)

5.38 The average impact per dwelling differs by the scale of the improvement required and the base position of the dwelling. (Table 5.5)

Table 5.5: Average annual fuel cost saving per dwelling and percentage decrease in fuel cost by base position

	EPC banding before improvements			
	G	F	**E**	**All GFE**
Scenario 1 – To F	£542 (22%)			£542 (22%)
Scenario 2 – To E	£1,053 (43%)	£338 (17%)		£463 (22%)
Scenario 3 – To D	£1,398 (57%)	£735 (37%)	£209 (16%)	£483 (29%)
Scenario 4 – 1 Up	£542 (22%)	£338 (17%)	£209 (16%)	£279 (17%)

5.39 The greater the scale of the improvements made, the greater the impact. Improving dwellings in EPC band G by one band (to F) would give an average annual fuel cost saving per dwelling of £542 (22% reduction) per annum compared to £1,053 (43% reduction) for improving this stock two bands to reach band E and £1,398 (57% reduction) for improving these dwellings three bands to reach band D.

5.40 Generally, however, the more efficient a dwelling is pre-improvement, the smaller the impact of improvements. The average annual fuel saving for improving a dwelling in EPC band G by one band is £542 (22% reduction). For dwellings in EPC band F, the corresponding figure is £338 (17% reduction), while for those in EPC band E, the saving decreases to £209 (16% reduction).

5.41 There are no clear differences in annual fuel cost savings by rurality. Within Scenario 1, dwellings in rural areas would save £525 per annum compared with £578 for dwellings in urban dwellings. (See Table A8.14). For Scenario 3, there is a considerable difference in the average fuel cost saving (£644 in rural areas, compared to £367 in urban areas). Note, however, that this is primarily due to a higher proportion of dwellings in rural areas than in urban areas being in bands G and F. For Scenario 4, the average annual fuel cost saving for rural dwellings is £326 compared to £246 in urban areas.

5.42 For the least efficient dwellings, the capital cost of improvements is lowest, and the financial gains are highest. It follows that the payback period is the shortest for these dwellings (Table 5.6). Scenario 1 has a mean payback period of 1.2 years, compared with 2.7 for Scenario 2, 5.5 for Scenario 3, and 3.5 year for Scenario 4.

Table 5.6: Mean payback period (years) by base position

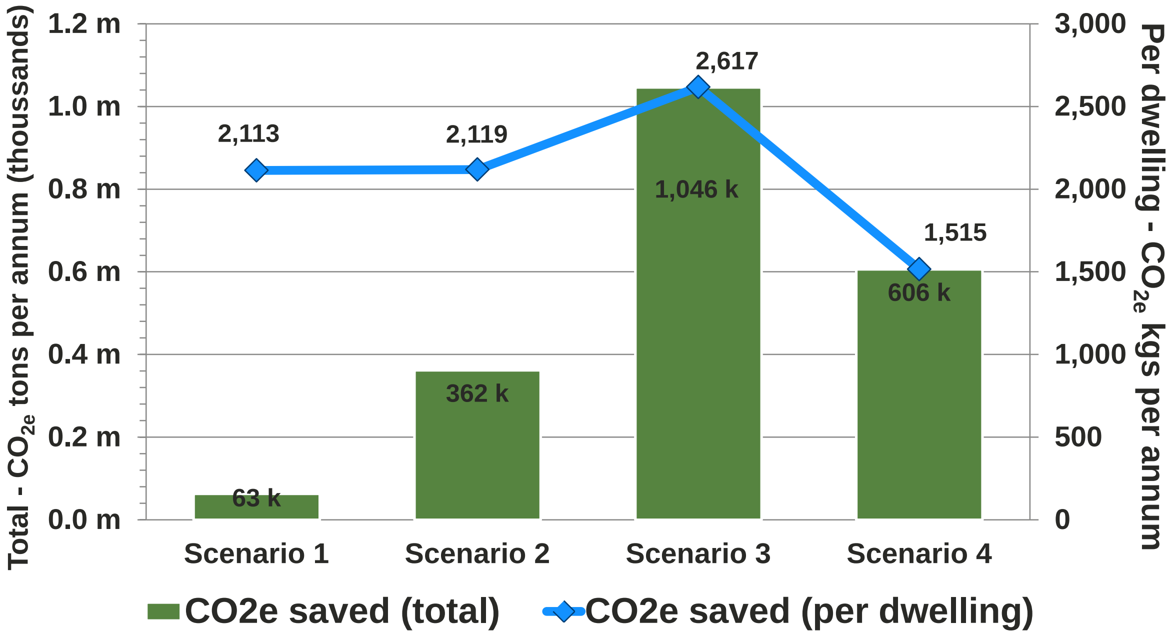
	EPC banding before improvements			
	G	**F**	**E**	**All target dwellings**
Scenario 1 – To F	1.2			1.2
Scenario 2 – To E	2.7	2.6		2.7
Scenario 3 – To D	6.0	5.6	5.1	5.5
Scenario 4 – 1 Up	1.2	2.6	5.1	3.5

Impact on CO_{2e} emissions

5.43 With regard to CO_{2e} savings, when all properties are improved:

- Scenario 1 would give an annual saving of 63 thousand tons per annum
- Scenario 2 would give an annual saving of 362 thousand tons per annum
- Scenario 3 would give an annual saving of 1.046 million tons per annum
- Scenario 4 would give an annual saving of 606 thousand tons per annum.

Figure 5.9: Total CO_{2e} saved (million tons per annum) and average per dwelling (kgs per annum) by scenario.



5.44 The average impact per dwelling again differs by the scale of the improvement required and the base position of the dwelling. (Table 5.7)

Table 5.7: Average annual CO_{2e} savings (kgs) per dwelling and percentage decrease in CO_{2e} by base position

	EPC banding before improvements			
	G	**F**	**E**	**All target dwellings**
Scenario 1 – To F	2,113 (19%)			2,113 (19%)
Scenario 2 – To E	3,317 (30%)	1,867 (16%)		2,119 (18%)
Scenario 3 – To D	5,036 (45%)	4,374 (37%)	1,222 (16%)	2,617 (28%)
Scenario 4 – 1 Up	2,113 (19%)	1,867 (16%)	1,222 (16%)	1,515 (16%)

5.45 In general, the larger the scale of the improvement made, the greater the impact on CO_{2e}. However, unlike fuel cost savings, there is no clear relationship between the level of efficiency prior to improvement and impact on CO_{2e} savings. Within Scenario 4, properties moving from G to F would see a 19% reduction in CO_{2e}, properties moving from F to E a 16% reduction, and properties moving from E to D properties a 16% reduction.

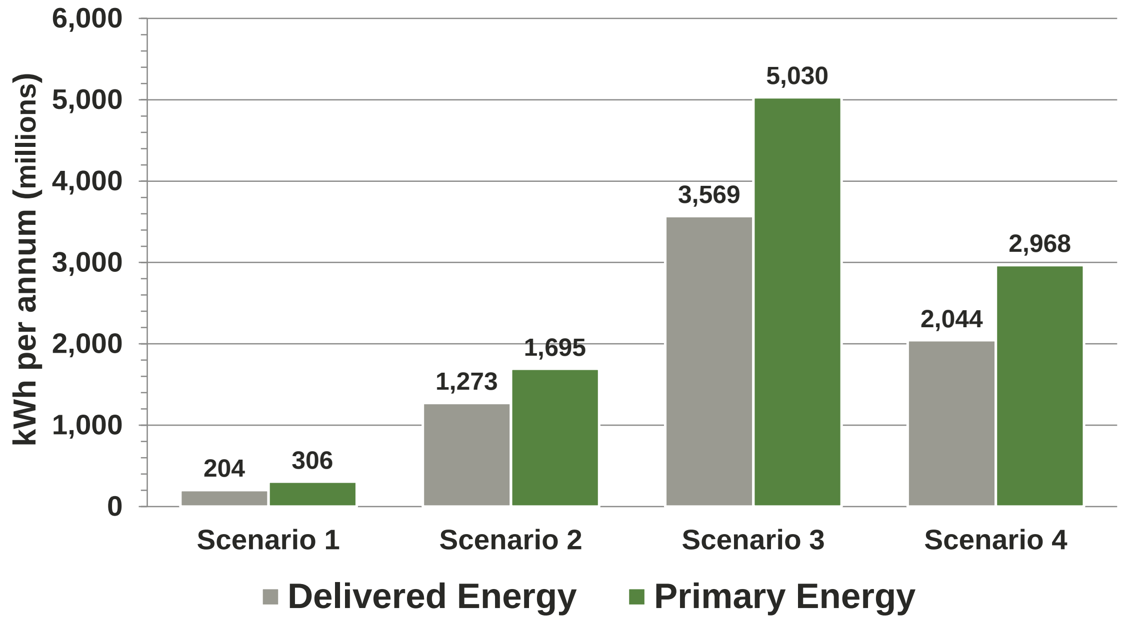
5.46 Across all four scenarios, on average, dwellings in rural areas would see a greater reduction in CO_{2e} than dwellings in urban areas[61] (Table A8.14).

Impact on primary and delivered energy

5.47 Figure 5.10 shows the overall reduction in delivered and primary energy that would result from the four scenarios:

- Scenario 1 would lead to an annual saving of 204m kWh per annum for delivered energy and 306m kWh per annum for primary energy
- Scenario 2 would lead to an annual saving of 1,273m kWh per annum for delivered energy and 1,695m kWh per annum for primary energy
- Scenario 3 would lead to an annual saving of 3,569m kWh per annum for delivered energy and 5,030m kWh per annum for primary energy
- Scenario 4 would lead to an annual saving of 2,044m kWh per annum for delivered energy and 2,968m kWh per annum for primary energy

Figure 5.10: Delivered and Primary Energy savings (kWh per annum) for capital costs to reach each scenario.



[61] For Scenario 4, the average reduction in CO_{2e} among dwellings in urban areas is around 25% less than for dwellings in rural areas.

5.48 As with energy costs, the larger the scale of improvement made, the greater the impact. Improving dwellings in EPC band G by one band to F would give an average reduction in primary energy of 10,313 kWh per annum (19% reduction) compared to 14,956 kWh per annum (27% reduction) for improving this stock two bands to reach band E and 25,267 kWh per annum (45% reduction) for a three band improvement to D.

5.49 Moving a dwelling one band up has a larger impact on the least efficient dwellings. The average reduction in primary energy annual fuel saving for improving a dwelling from G to F is 10,313 kWh per annum (19% reduction). The corresponding figure for F to E improvements is 8,829 (16% reduction), and 6,184 (16% reduction) for E to D improvements.

Table 5.8: Average reduction in primary energy (kWh per annum) per dwelling and percentage decrease by base position

	EPC banding before improvements			
	G	**F**	**E**	**All target dwellings**
Scenario 1 – To F	10,313 (19%)			10,313 (19%)
Scenario 2 – To E	14,956 (27%)	8,829 (16%)		9,894 (18%)
Scenario 3 – To D	25,267 (45%)	20,305 (36%)	6,184 (16%)	12,583 (27%)
Scenario 4 – 1 Up	10,313 (19%)	8,829 (16%)	6,184 (16%)	7,424 (16%)

5.50 The pattern in delivered energy is similar.

Effect of "in-use"factors[62]

5.51 In-use factors are designed primarily to account for differences in performance of retrofit energy efficiency improvements in-situ compared to laboratory testing. These differences can arise due to:

- imperfect installation
- obstructions to insulating parts of walls, e.g. due to garages or conservatories
- natural variations in the thermal performance of structural and fabric elements that cannot be fully determined by the assessment, e.g. the U-values of un-insulated walls.

5.52 The in-use factor is not intended to account for occupants changing their behaviour, for example, comfort taking to achieve a warmer home[63].

[62] Paragraph 5.53 to 5.62 were provided by Scottish Government analysts
[63] DECC, "How the Green Deal will reflect in-situ performance of energy efficiency measures" https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48407/5505-how-the-green-deal-will-reflect-the-insitu-perfor.pdf

5.53 One of the key requirements of the energy efficiency modelling conducted by this research project was to ensure results were consistent with those generated by Energy Performance Certificates (EPCs). As the underlying SAP and RdSAP software does not have the facility to incorporate in-use factors, these have not been included in the main research findings reported in this Chapter, nor have they been included in the detailed archetype modelling examples published with this report.

5.54 However, it is important that the impact of in-use factors is considered, especially in estimating the impact on CO_{2e} reductions, generated by installing improvement measures. In-use factors will also affect estimates of energy use and running costs. These will be fully accounted for in the Business and Regulatory Impact Assessment (BRIA) produced by the Scottish Government.

5.55 In order to provide an indication of the effect of in-use factors, the following section illustrates the impacts on headline CO_{2e} consumption and fuel cost results, for two of the policy scenarios.

5.56 In-use factors applied are provided by the Department for Energy and Climate Change (DECC)[64]. These factors are applied in assessments of eligibility for the Green Deal and for calculating the consequences of improvements funded under ECO. These have been interpreted for application to the measures included in this report as shown in Table 5.9, in descending order of impact.

Table 5.9: DECC In-use factors as applied to individual modelled measures – in descending order

Code	Improvement Measure	In-Use Factor
M24	room thermostat	0.5
M25	programmer for heating system	0.5
M26	TRVs	0.5
M27	full controls package (r/stat, programmer and TRVs)	0.5
M28	Auto charge control	0.5
M1	loft insulation	0.35
M4	cavity wall insulation	0.35
M3	room in the roof insulation	0.25
M5	solid wall insulation	0.25
M14	replace gas boiler with condensing boiler 88%	0.25
M15	replace oil boiler with condensing boiler 90%	0.25
M16	full gas central heating system inc controls	0.25
M17	full oil central heating system inc controls	0.25
M18	full biomass central heating system inc controls	0.25
M22	air source heat pump	0.25

[64] *Ibid.*

M35	Air to Air heat pump	0.25
M36	replace secondary heating with one more efficient	0.25
M37	electric CPSU with radiators and controls on E18 tariff	0.25
M2	flat roof insulation	0.15
M6	floor insulation	0.15
M7	double glazing to 1.8	0.15
M8	secondary glazing to 2.4	0.15
M9	triple glazing to 1.4	0.15
M10	insulated external doors	0.15
M11	hot water tank jacket 80mm	0.15
M12	draughtproof windows and doors	0.15
M13	baffle / damper to open fire	0.15
M19	fan electric storage heaters with auto charge control	0.1
M20	quantum storage heaters	0.1
M21	full electric radiator system inc controls - off peak tariff	0.1
M23	ground source heat pump	0.1
M34	Cylinder stat for hot water cylinder	0.1
M29	Solar thermal 4m2	0
M30	PV 2kWp	0
M31	2m diameter wind turbine on roof	0
M32	5m wind turbine on stand-alone mast	0
M33	low energy lighting 100%	0
M38	switch to E24 tariff	0

5.57 The in-use factors in Table 5.9 range from 0 to 0.5, which corresponds to the benefits of these improvement measures being reduced by between 0% and 50%, when compared to results generated by EPC reports.

5.58 The impact of applying in-use factors to headline results on CO2 consumption and fuel costs for policy scenarios 2 and 3 is illustrated in Table 5.10.

5.59 The impact of in-use factors on CO2 consumption is a 28% reduction on headline results for both Scenarios 2 and 3. This reduces overall CO2 savings by 103k tons under Scenario 2 to 259k tons and by 289k tons under Scenario 3 to 757k tons.

5.60 The impact of in-use factors on fuel costs is a 26% reduction on headline results for both Scenarios 2 and 3. This reduces overall fuel costs savings by £20m under Scenario 2 to £59m and by £50m under Scenario 3 to £143m.

Table 5.10: DECC In-use factors as applied to headline results on CO2 consumption and fuel costs for Policy Scenarios 2 and 3.

		Scenario 2	Scenario 3
		All dwellings to reach Band E	All dwellings to reach Band D
Number of dwellings improved		170,708	400,548
Mean CO_2 consumed pre improvement (kg per annum)		11,604 kg	9,319 kg
	Reduction	2,119 kg	2,617 kg
	Reduction after In-Use-Factors	1,517 kg	1,894 kg
	difference	602 kg	723 kg
	% difference	-28%	-28%
Overall CO_2 consumed pre improvement (k tons per annum)		1,981 k tons	3,733 k tons
	Reduction	362 k tons	1,046 k tons
	Reduction after In-Use-Factors	259 k tons	757 k tons
	difference	103 k tons	289 k tons
	% difference	-28%	-28%
Mean fuel cost pre improvement (£)		£2,062	£1,642
	Reduction	£463	£483
	Reduction after In-Use-Factors	£344	£359
	difference	£119	£124
	% difference	-26%	-26%
Overall fuel cost pre improvement (£m)		£352 m	£658 m
	Reduction	£79 m	£193 m
	Reduction after In-Use-Factors	£59 m	£143 m
	difference	£20 m	£50 m
	% difference	-26%	-26%

6 SUMMARY OF TECHNICAL ISSUES AND ASSUMPTIONS

6.1 This research project has attempted to be completely transparent in the use of the SHCS dataset in terms of its approach to developing the initial dwelling typology and the individual archetypes, its modelling of the base case archetypes, and the assumptions made in the modelling of measures to improve the least efficient dwellings in the private sector stock.

6.2 This section sets out the background to the SAP and RdSAP methodologies, their relationship with each other and with the SHCS data set that was used as the basis of the 355 archetypes, and how this affects the modelling of the archetypes. During this project there have been regular meetings with the REEPS RAG, and feedback from the REEPS Working Groups and subgroups that have raised various technical issues and concerns about aspects of SAP, RdSAP, the modelling assumptions and the improvement measures modelled that have informed the approach. A log of all of these queries, questions, and concerns were kept so they could be addressed in this report.

6.3 This area is one that is continually evolving, not just the knowledge about energy in dwellings, but also the SAP and RDSAP models themselves. This section summarises some of the key technical issues, the assumptions used, and how these relate to the outputs of the modelling.

6.4 These issues have been organised below into 5 sub-sections: SAP and RdSAP issues; specific technical issues; Improvement costs Issues; Occupant related issues; and Miscellaneous issues.

SAP and RdSAP issues

Evolution of SAP and RdSAP

6.5 Both the Standard Assessment Procedure (SAP) and the Reduced Data Standard Assessment Procedure (RdSAP) use the same calculation methodology and algorithms to calculate various energy performance indicators for a dwelling, e.g. the SAP Score, the EPC Band, the Environmental Impact Score, Environmental Impact Band, the SAP fuel costs, the SAP delivered energy, the SAP primary energy and the SAP carbon dioxide emissions.

6.6 That there are two approaches to calculate the same energy performance of a dwelling reflects the evolution of SAP and the implementation of the EU's Energy Performance Building Directive (EPBD). When SAP emerged in 1993 it was initially a methodology to compare two private sector energy rating schemes. SAP took on an independent life when it was then incorporated into the 1995 English and Welsh Building Regulations, and later into the 1997 Scottish Building Regulations, as one method to demonstrate compliance with the respective energy efficiency standards for new build dwellings. As demonstrating compliance for new build dwellings requires the calculation of individual U-values for, and the heat loss through, the different fabric components of the dwelling, the SAP methodology uses U-values and the area dimensions of the different fabric components as inputs into the calculation methodology. The presumption within SAP was that a person was doing the calculation using floor plans and elevations, and therefore this information would be available.

6.7 The original SAP methodology has evolved over time, so that SAP 1998, SAP 2001, SAP 2005, and SAP 2009 come and go. The current version is SAP 2012 version 9.92[65].

6.8 In preparing for the introduction of the energy labelling of all dwellings at the point of sale or rent (energy rating of existing dwellings came into effect in Scotland on January 1st, 2009) a consensus emerged between the energy rating industry and software developers, the BRE (who developed the SAP methodology, and continue to maintain it) and the government, that a full SAP calculation was not feasible. For example, it would be very difficult to identify all the layers of an existing wall construction to allow a U-value to be calculated without intrusive surveys. Two important factors that influenced the thinking on extending energy rating to existing dwellings were the cost of producing the energy rating, and the length of time it would take to complete the survey. The more complicated the survey, the more information that would need to be collected This would lead to the survey being longer and more expensive to complete with possible consequences of market reluctance and householder hostility.

6.9 RdSAP evolved as a way of completing the SAP calculation for existing dwellings. Rather than entering the specific dimensions of all of the fabric components, a geometric model was developed to calculate the fabric components from a minimum data set. Rather than calculate the U-values of the individual fabric components, default U-values were adopted taking account of the known insulation levels, construction type of the component, and the age of the dwelling. RdSAP utilises other defaults for energy-related factors, such as the presence of flues and extract fans, and the air tightness of a dwelling. Initially, when RdSAP was introduced in 2009 these defaults could not be altered, but with the introduction of RdSAP 2009 version 9.91 (in October 2012) it became allowable for default U-values to be overwritten by assessors under specific, defined conditions. All of the default values used in RdSAP are set out in various tables within Appendix S of the SAP 2012 manual. When the REEPS modelling of the archetypes started, a working RdSAP 2012 (version 9.92) program was not available from any of the approved software developers, so an approved full SAP program was used (i.e. NES's Plan Assessor v6.1). RdSAP 2012 (also known as RdSAP version 9.92) became available when it came into effect across the UK on December 7th, 2014.

Comparing the SAP and RdSAP approaches

6.10 The two approaches are compared here by way of an example of a rectangular, 3-bedroomed 1930's detached bungalow with a cavity wall with a

[65] The SAP 2012 manual, which sets out the full methodology and calculation algorithms, is available at the BRE website: http://www.bre.co.uk/sap2012/page.jsp?id=2759.

south facing front. The internal floor area of this bungalow is (9 x 8) 72 m^2, with a floor to ceiling storey height of 2.5m, with a typical window area. There are 2 external doors: one in the hall and one in the kitchen. There is a window in each room spread across all 4 elevations. The resultant dimensional data for this dwelling for both SAP 2012 and RdSAP 2012 is set out in Table 6.1.

Figure 6.1: Floor plan of detached bungalow

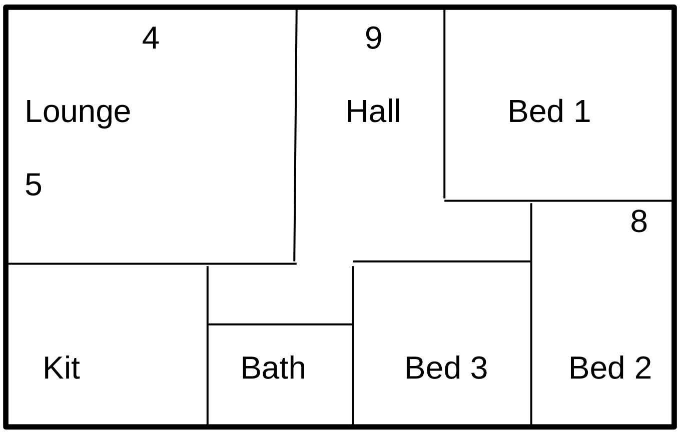


Table 6.1: Comparing SAP and RdSAP entries for the same dwelling

	SAP	**RdSAP**
Total floor area (TFA)	9 x 8 = 72m^2	9 x 8 =72m^2
Heat loss floor area	9 x 8 = 72m^2	assumed from floor area = 72m^2
Heat loss roof area	9 x 8 = 72m^2	assumed from floor area = 72m^2
Gross heat loss wall area	((8 x 2.5) + (9 x 2.5)) x 2) = 85m^2	exposed perimeter(9 + 8 + 9 + 8)x 2.5m height = 85m^2
Net heat loss wall area	85m^2 – window areas and door areas (see below) = 60.5m^2	85m2 – window area and door area (see below) = 65.647m^2
Window area	each window measured with details about frame, type of glazing, gap in multiple glazing, whether low –e coated, whether inert gas filled, and orientation – lounge = 3m^2 to front and 2.07m^2 to left side. Hall = 1.26m^2 front. Bed1 = 3m^2 to front and 2.1m^2 to right. Bed 2 = 2.07m^2 to rear. Bed 3 = 2.07m^2. Bath = 0.864m^2. kit = 2.07m^2 to rear and 2.07m^2 to left side. Total = 20.54m^2	Calculated by formula in Appendix S (.122 x TFA + 6.875) = 15.659m^2 Orientation – east / west.
Door area	Front door (2.1 x 1) = 2.1m^2 Rear door (2.1 x 0.9) = 1.89m^2 Total 3.99m^2	2 doors x RdSAP default of 1.85m^2 = 3.70m^2
Main living area %	Lounge area / TFA = 20 /72 x 100% = 27.78%	4 habitable rooms – 25% from Appendix S table S16

6.11 From Table 6.1, the SAP and RdSAP approaches produce different net wall areas (with implications for the total heat loss of the dwelling) as a result of using the typical window area approach in RdSAP compared to the full SAP calculation. RdSAP also assumes all windows are east-west facing, which is not the case here. These differences could be reduced by measuring the actual windows during the RdSAP survey, as could the impact of the very different solar gains from the different orientations, as RdSAP does have the facility to enter specific window details (although most RdSAP assessors probably do not use it). There would be some further difference in the calculated heat loss of the dwelling as a result of the difference in the total door area and the difference in the main living area percentage, neither of which can be adjusted in RdSAP currently.

6.12 Keeping the other data entry items the same as much as possible in the two programs, the overall difference in the SAP score produced by full SAP 2012 and RdSAP 2012 programs for this dwelling is small, but there is a difference. SAP 2012 produced a SAP score of 60, while RdSAP 2012 produced a SAP rating of 58. When the full window details were entered into RdSAP, the resultant difference is reduced as the RdSAP SAP score increases to 59.

6.13 More complicated dwellings are likely to give rise to much greater variation in the SAP scores produced by the two approaches where the actual dimensional details (and in particular, the windows areas) diverge significantly from the defaults. However, as seen above, it is possible to overwrite many of the details in RdSAP.

6.14 An important qualifier in this sample comparison was "keeping the other data entry items the same as much as possible". Both of these sample assessments used the RdSAP default U-values. This issue is discussed further in relation to the technical issues raised about the use of SAP and RdSAP.

SAP 2012 modelling of the SHCS dataset

6.15 The starting point for modelling the SAP scores for all of the 355 REEPS archetypes was the SHCS data collected during the 2010 - 2012 surveys. The SHCS was designed to collect the necessary data to allow the SAP scores and EPC bandings to be calculated as part of the outputs from the SHCS data analysis. A complication here is that the revisions to RdSAP data set are occurring faster than the revisions to the SHCS form. While many of the RdSAP revisions since 2012 have been to allow new technologies to be included within the RdSAP methodology, these technologies have not yet percolated into mainstream housing, and especially not amongst the dwellings with the poorer ratings. These are not the only changes. For instance, the SHCS does not collect the number of doors in a dwelling or whether the doors are insulated; it does not collect whether the windows are draught proofed; it does not collect any information about the length or construction of party walls; it does not collect whether solid walls or stone walls pre-1976 are lined or not; nor does the SHCS collect the age of the room of the roof (if one is present). To accommodate these data differences, assumptions are necessary.

6.16 Effectively a 2-page survey form was created to collate the necessary SAP data from the SHCS data set for each archetype (a sample is included in Appendix 11 of this report).

6.17 Then, the dataset for each archetype was to be converted into a full SAP data set. To do so required:

- the exposed perimeters for each storey of each dwelling to be converted to gross wall areas
- the areas and perimeters to be converted to internal areas and perimeters where the SHCS data set had measured externally (the formulae for the different dwelling types are set out in Table S2 in Appendix S of the SAP 2012 manual)
- the storey height of upper floors to be increased by 0.25m (in keeping with the procedure set out in Appendix S that RdSAP uses to work out the total volume of a dwelling and the total wall area)
- the RdSAP window areas to be calculated for typical, more than typical, and less than typical options as identified by the SHCS survey (again, the formulae for the different dwelling types and age bands are set out in Table S4 of Appendix S of the SAP 2012 manual)
- the U-values for the walls, roofs, and floors to be identified for the respective construction, age of the dwelling, and level of insulation present
- the U-value for the glazing to be identified
- the U-value for the doors to be identified.

6.18 As the SHCS data was entered into the full SAP 2012 program, it was also entered into a RdSAP 2009 (version 9.91) program to identify the RdSAP default U-values for the respective walls, roofs and floor constructions of each archetype. This tandem data entry approach was also used to identify the window areas for each archetype, and again for identifying the areas and default U-values of the different components of the room in the roof.

6.19 Assumptions used included:

- a house or a bungalow was assumed to have 2 doors; a flat was assumed to have 1 door, which was assumed to be located within the unheated corridor wall (where this was present) (these were the assumptions in RdSAP before v9.91 was introduced in October 2012)
- all doors were assumed to be uninsulated with a U-value of 3.0 W/m^2K (the assumption in RdSAP v9.90, i.e. the version before v9.91 was introduced in October 2012)
- stone walls in pre-1930 dwellings where the wall thickness was greater than 450mm had an internal lining finish; solid brick walls in dwellings of the same age were assumed to be plastered on the hard (so no internal lining)
- the SHCS records wall thicknesses by one of 3 options: less than 450mm thick; between 450mm and 700mm thick; and more than 700mm thick: stone

walls with a SHCS thickness of less than 450mm were assumed to be 400mm thick for the purposes of SAP (i.e. a midpoint between common stone wall thicknesses of 350mm and the 450mm SHCS cut-off); stone walls with a thickness of between 450 mm and 700mm were assumed to be 575mm thick for the purposes of SAP (the mean thickness); and stone walls with a thickness of greater than 700mm were assumed to be 800mm thick for the purposes of SAP (i.e. a mid point between the 700mm SHCS starting point and 900mm).

- the age of the room in the roof was the same as the age of the main dwelling
- the flat ceiling in the room in the roof was insulated to the main standard as the rest of the loft, but that the stud walls and slopes were 'as built'
- the number of habitable rooms was the number identified in the SHCS minus 1 if the kitchen was identified as a 'kitchen only' (as the SHCS habitable room count includes the kitchen); if the kitchen was identified as including another purpose (e.g. living or dining) then it was not subtracted from the habitable room count
- the number of heated habitable rooms was assessed from the room by room record data collected by the SHCS which includes assessing whether fixed heating is present
- there was draught lobby on a house or a bungalow if the SHCS indicated the presence of a porch; that there was a draught lobby on a flat or maisonette if the SHCS identified that there was a circulation area in the common block and that there were entrance doors on the front and back of the common block
- the windows were draught proofed if double glazed and not draught proofed if single glazed (these were the assumptions in RdSAP before v9.91 was introduced in October 2012)
- the doors were not draught proofed in pre-1991 dwellings unless they also had post 2002 double glazing
- the windows were orientated east - west (this is the assumptions in RdSAP unless the specific window details are entered)
- the increase of the typical window area by 25% where the SHCS identified the window area as 'more than typical', and the reduction of the typical window area by 25% where the SHCS identified the window area as 'less than typical'
- the pro rata split of the calculated window area between the main dwelling and any extensions based on the percentage of total floor area
- the length of the party wall, where the dwelling type would have a party wall, was estimated from the floor area and exposed perimeter. This was done on a case by case basis or on a trial and error basis, to obtain a fit. The construction of the wall type was based on the external wall of the dwelling (so if the external walls were cavity, then the party wall was assumed to be a cavity wall. All cavity walls and party walls were assumed to be unknown with regard to their insulation. The U-values ascribed to the different party walls were those set out in Table S8B of Appendix S.)

6.20 The SHCS collects data on the number of flues and number of extract fans within each dwelling, so there was no need for assumptions here within the full SAP data entry (although RdSAP makes assumptions on these items, and so there may be slight variations).

6.21 Before the full modelling exercise of the archetypes in SAP 2012 commenced, the data set for 12 dwellings was entered into both an RdSAP 2009 version 9.91 program and into an approved full SAP 2009 (NES's Plan Assessor 5.5.6 program) using the above assumptions and the results were compared. In all cases, the results were within ±2 SAP points (and 7 of the 12 achieved the same SAP score). The error bar used in assessing the accuracy of SAP programs as part of the approval process is ±4 SAP points.

6.22 One climatic assumption was made with the modelled archetypes. Both SAP and RdSAP use the post code to identify the degree day climatic zone, wind speed, and height above sea level used within the energy calculations. All of the archetypes were modelled on the Dalkeith post code of EH22. This post code has been identified previously by the SHCS as the median Scottish post code with regard to height above sea level, with a height of 61m above sea level. The post code and climatic zone has a variable role with the SAP / RdSAP process (see Appendix 6 where this is discussed in more detail).

U-value assumptions in RdSAP

6.23 The default U-values used in RdSAP are set out in various tables within Appendix S of the SAP 2012 manual:

- Table S7 - wall U-values (see Figure 6.2)
- Table S8B - party wall U-values (see Figure 6.3)
- Table S9 - roof U-values where thickness of insulation is known (see Figure 6.4)
- Table S10 - roof U-values where thickness of insulation is unknown (see Figure 6.5)
- Table S11 - thicknesses of insulation in ground floor (see Figure 6.6).

6.24 RdSAP includes a range of default U-values of common wall types as standard: granite or whinstone, sandstone, solid brick, cavity, timber frame, cob and system built (see Figure 6.2) and organised by age bands[66]. Within Table S7, it can be seen that up to 1964, the important determinant for unimproved walls is the type of wall construction. From 1965 (and the arrival of the Scottish Building Regulations) the important determinant is actually the age band of the dwelling because of the increasingly higher insulation standards required to meet the respective Building Regulations. It is to be noted that for the U-values for pre-1965 stone walls, the Table refers to a

[66] The SAP age bands for Scotland, as set out on p115 of the the SAP 2012 manual, are: Age Band A: pre-1919; Age Band B: 1919-1929; Age Band C: 1930-1949; Age Band D: 1950-1964; Age Band E: 1965-1975; Age Band F: 1976-1983; Age Band G: 1984-1991; Age Band H: 1992 -1998; Age Band I: 1999-2002; Age Band J: 2003-2007; Age Band K: 2008-2011; Age Band L: 2012 onwards

footnote where the U-value is derived from formulae that varies by the type of stone and the thickness of the wall.

Figure 6.2: Table S7 Wall U-values in RdSAP 2012[67]

Table S7 : Wall U-values – Scotland

Age band	A	B	C	D	E	F	G	H	I	J	K	L
Wall type												
Stone: granite or whinstone as built	a	a	a	a	1.7 b	1.0	0.60	0.45	0.45	0.30	0.25	0.22
Stone: sandstone or limestone as built	a	a	a	a	1.5 b	1.0	0.60	0.45	0.45	0.30	0.25	0.22
Solid brick as built	2.1	2.1	2.1	2.1	1.7	1.0	0.60	0.45	0.45	0.30	0.25	0.22
Stone/solid brick with 50 mm external or internal insulation	0.60	0.60	0.60	0.60	0.55	0.45*	0.35*	0.30*	0.30*	0.21*	0.19*	0.17*
Stone/solid brick with 100 mm external or internal insulation	0.35	0.35	0.35	0.35	0.35	0.32*	0.24*	0.24*	0.21*	0.19*	0.17*	0.14*
Stone/solid brick with 150 mm external or internal insulation	0.25	0.25	0.25	0.25	0.25	0.21*	0.18*	0.18*	0.17*	0.15*	0.14*	0.12*
Stone/solid brick with 200 mm external or internal insulation	0.18	0.18	0.18	0.18	0.18	0.17*	0.15*	0.15*	0.14*	0.13*	0.12*	0.10*
Cob as built	0.80	0.80	0.80	0.80	0.80	0.80	0.60	0.60	0.45	0.30	0.25	0.22
Cob with 50 mm external or internal insulation	0.40	0.40	0.40	0.40	0.40	0.40	0.35*	0.35*	0.30*	0.21*	0.19*	0.17*
Cob with 100 mm external or internal insulation	0.26	0.26	0.26	0.26	0.26	0.26	0.24*	0.24*	0.21*	0.19*	0.17*	0.14*
Cob with 150 mm external or internal insulation	0.20	0.20	0.20	0.20	0.20	0.20	0.18*	0.18*	0.17*	0.15*	0.14*	0.12*
Cob with 200 mm external or internal insulation	0.16	0.16	0.16	0.16	0.16	0.16	0.15*	0.15*	0.14*	0.13*	0.12*	0.10*
Cavity as built	2.1	1.6	1.6	1.6	1.6	1.0	0.60	0.45	0.45	0.30	0.25	0.22
Unfilled cavity with 50 mm external or internal insulation	0.60	0.53	0.53	0.53	0.53	0.45	0.35*	0.30*	0.30*	0.25*	0.19*	0.17*
Unfilled cavity with 100 mm external or internal insulation	0.35	0.32	0.32	0.32	0.32	0.30	0.24*	0.21*	0.21*	0.19*	0.17*	0.14*
Unfilled cavity with 150 mm external or internal insulation	0.25	0.23	0.23	0.23	0.23	0.21	0.18*	0.17*	0.17*	0.15*	0.14*	0.12*
Unfilled cavity with 200 mm external or internal insulation	0.18	0.18	0.18	0.18	0.18	0.17*	0.15*	0.15*	0.14*	0.13*	0.12*	0.10*
Filled cavity	0.50	0.50	0.50	0.50	0.50	0.40	0.35	0.45†	0.45†	0.30†	0.25†	0.22†
Filled cavity with 50 mm external or internal insulation	0.31	0.31	0.31	0.31	0.31	0.27	0.25*	0.25*	0.25*	0.25*	0.25*	0.17*
Filled cavity with 100 mm external or internal insulation	0.22	0.22	0.22	0.22	0.22	0.20	0.19*	0.19*	0.19*	0.19*	0.19*	0.14*
Filled cavity with 150 mm external or internal insulation	0.17	0.17	0.17	0.17	0.17	0.16	0.15*	0.15*	0.15*	0.15*	0.15*	0.12*
Filled cavity with 200 mm external or internal insulation	0.14	0.14	0.14	0.14	0.14	0.13	0.13*	0.13*	0.13*	0.13*	0.12*	0.10*
Timber frame as built	2.5	1.9	1.9	1.0	0.80	0.45	0.40	0.40	0.40	0.30	0.25	0.22
Timber frame with internal insulation	0.60	0.55	0.55	0.40	0.40	0.40	0.40†	0.40†	0.40†	0.30†	0.25†	0.22†
System build as built	2.0	2.0	2.0	2.0	1.7	1.0	0.60	0.45	0.45	0.30	0.25	0.22
System build with 50 mm external or internal insulation	0.60	0.60	0.60	0.60	0.55	0.45	0.35*	0.30*	0.30*	0.21*	0.19*	0.17*
System build with 100 mm external or internal insulation	0.35	0.35	0.35	0.35	0.35	0.32*	0.24*	0.24*	0.21*	0.19*	0.17*	0.14*
System build with 150 mm external or internal insulation	0.25	0.25	0.25	0.25	0.25	0.21*	0.18*	0.18*	0.17*	0.15*	0.14*	0.12*
System build with 200 mm external or internal insulation	0.18	0.18	0.18	0.18	0.18	0.17*	0.15*	0.15*	0.14*	0.13*	0.12*	0.10*

a See equations in S5.1.1
b Or from equations S5.1.1 if that is less.
* wall may have had internal or external insulation when originally built; this applies only if insulation is known to have been increased subsequently (otherwise 'as built' applies)
† assumed as built
If a wall is known to have additional insulation but the insulation thickness is unknown, use the row in the table for 50 mm insulation

[67] Source: (2014) The Government's Standard Assessment Procedure for Energy Rating of Dwellings (2012 edition), p132, BRE, Garston

6.25 RdSAP includes a range of default U-values of common wall types as standard either granite or whinstone. The degree of heat loss varies depending on the dwelling type and nature of the party wall (see Figure 6.3).

Figure 6.3: Table S8B Party Wall U-values in RdSAP 2012[68]

Table S8B : U-values of party walls

Party wall type	Party wall U-value
Solid masonry / timber frame / system built	0.0
Cavity masonry unfilled	0.5
Cavity masonry filled	0.2
Unable to determine, house or bungalow	0.25
Unable to determine, flat or maisonette	0.0

6.26 RdSAP uses two approaches for establishing the default U-value, one where the thickness of the insulation is known for certain roof types (see Figure 6.4), and another where the thickness of insulation is unknown (see Figure 6.5).

Figure 6.4: Table S9 Roof U-values (known insulation) in RdSAP[69]

Table S9 : Roof U-values when loft insulation thickness at joists is known (for insulation between joists including insulation at flat ceiling of a roof room)

Insulation thickness at joists (mm)	Assumed roof U-value (W/m²K)	
	Slates or tiles	Thatched roof
None	2.3	0.35
12	1.5	0.32
25	1.0	0.30
50	0.68	0.25
75	0.50	0.22
100	0.40	0.20
150	0.30	0.17
200	0.21	0.14
250	0.17	0.12
270	0.16	0.12
300	0.14	0.11
350	0.12	0.10
>= 400	0.11	0.09

[68] Source: (2014) The Government's Standard Assessment Procedure for Energy Rating of Dwellings (2012 edition), p134, BRE, Garston
[69] Source: (2014) The Government's Standard Assessment Procedure for Energy Rating of Dwellings (2012 edition), p135, BRE, Garston

Figure 6.5: Table S10 Roof U-values (unknown insulation) in RdSAP[70]

Table S10 : Assumed roof U-values when Table S9 does not apply

Age band	Assumed Roof U-value (W/m²K) [(a)]						
	Pitched, slates or tiles, insulation between joists or unknown	Pitched, slates or tiles, insulation at rafters	Flat roof [(b)]	Room-in-roof, slates or tiles	Thatched roof [(c)]	Thatched roof, room-in-roof	Park home
A, B, C, D	2.3 (none)	2.3 [(1)]	2.3 [(1)]	2.3 [(1)]	0.35	0.25	-
E	1.5 (12 mm)	1.5 [(1)]	1.5 [(1)]	1.5 [(1)]	0.35	0.25	-
F	0.68 (50 mm)	0.68 [(1)]	0.68 [(1)]	0.80 [(1)]	0.35	0.25	1.7
G	0.40 (100 mm)	0.40 [(1)]	0.40 [(1)]	0.50 [(1)]	0.35	0.25	0.6
H	0.30 (150 mm)	0.35 [(1)]	0.35 [(1)]	0.35 [(1)]	0.35	0.25	-
I	0.26 (150 mm)	0.35 [(1)]	0.35 [(1)]	0.35 [(1)]	0.35	0.25	0.35
J	0.16 (270 mm)	0.20	0.25	0.30	0.30	0.25	-
K	0.16 (270 mm)	0.20	0.25 [(2)]	0.25 [(2)]	0.25 [(2)]	0.25 [(2)]	0.30
L	0.16 [(3)] (270 mm)	0.18	0.18	0.18	0.18	0.18	-

[(a)] If the roof insulation is "none" use U = 2.3 (all roof types).

6.27 RdSAP calculates the floor U-value from formulae taking account of the area to perimeter ratio, floor construction and the thickness of insulation. As floor insulation will not usually be known unless an intrusive survey is carried out, RdSAP has published default insulation thicknesses to use in the U-value calculations (see Figure 6.6). The other variables in the equation would be collected during a survey.

Figure 6.6: Table S11 Floor insulation thicknesses in RdSAP[71]

Table S11 : Basis for floor U-value calculation for ground floors when insulation thickness is unknown

Age band	Floor construction [(1)]	All-over floor insulation [(2)]			
		England & Wales	Scotland	Northern Ireland	Park home [(3)]
A, B	suspended timber [(4)]	none	none	none	-
C to F	solid	none	none	none	none
G	solid	none	none	none	25 mm
H	solid	none	25 mm	25 mm	-
I	solid	25 mm	50 mm	50 mm	50 mm
J	solid	75 mm	75 mm	-	-
K	solid	100 mm	100 mm	100 mm	70 mm
L	solid	100 mm	120 mm	100 mm	-

[(1)] Where floor construction is unknown

[(2)] For floors which have retro-fitted insulation, use the greater of 50 mm and the thickness according to the age band.

[(3)] Suspended timber in all cases.

[(4)] Solid ground floor if underfloor heating.

[70] Source: (2014) The Government's Standard Assessment Procedure for Energy Rating of Dwellings (2012 edition), p136, BRE, Garston
[71] Source: (2014) The Government's Standard Assessment Procedure for Energy Rating of Dwellings (2012 edition), p137, BRE, Garston

6.28 These default U-values were used in the SAP 2012 modelling of the 355 archetypes. Other U-values could have been used. For the future of REEPS, it is important that it is possible to replicate the SAP results in RdSAP. So, while it is possible to overwrite U-values in RdSAP programs, the protocol conventions are quite explicit governing the over-writing of U-values and the documentary evidence that must be collected to support this action. These conventions limit most assessors to using the default U-values.

6.29 The default double glazing U-values for double and triple glazing were taken from Table 6a of the SAP 2012 manual rather than using the limited RdSAP defaults in Appendix S, to more appropriately reflect the common forms of double glazing found in Scottish dwellings. RdSAP does allow for the use of Table 6a glazing U-values to be used instead of the Appendix S defaults, so this is consistent with the RdSAP methodology.

Fuel costs used in SAP and RdSAP

6.30 Are there differences between real world fuel prices, and those used in SAP and RdSAP modelling? In particular, how do assumed and actual costs of biomass fuels compare?

6.31 SAP and RdSAP do not just use one set of fuel prices. They both use the same fuel cost basis, but within the modelling for EPCs, different reference fuel costs are used for specific purposes (see Appendix 7 for a fuller discussion on this).

6.32 SAP and RdSAP assume all fuels are bought in, that is, they do not take account of the possibility of 'free fuel', whether this comes from collecting sea coal from beaches, getting free coal because of past employment as a coal miner, collecting wood, or coppicing one's own wood lot.

Supplier switching / Tariff switching / Dual Fuel prices

6.33 How is switching supplier / switching tariffs / dual fuel tariffs accommodated for in the modelling of improvements?

6.34 Comparing the impact of switching suppliers, or buying into dual fuel discount tariffs, is outwith the ability of RdSAP or SAP to accommodate per se. There is no ability within the program to change unit rates to see how these would affect a household's fuel bills. The information from the energy consumption outputs from the two programs could be used and compared but would have to be done either by hand or in separate software (e.g. a spread sheet).

6.35 There is a limited ability to assess the impact of switching the type of electricity tariff a dwelling is on for given heating systems in SAP and RdSAP. Effectively, there are 4 electricity rates embedded within SAP and RdSAP - standard domestic rate, a traditional off peak rate, an 18-hour rate and a 24-hour rate. So it is possible to assess electric storage heaters on standard domestic rate, a traditional off peak rate, and a 24-hour rate; it is possible to assess electric room heaters on standard domestic rate, a traditional off peak rate and a 24-hour rate; it is possible to assess electric wet systems on standard domestic rate, a traditional off peak rate and an 18-hour rate. The results can then be evaluated to determine if there are any benefits for the householder to move them from one generic tariff to another. Several of the improvement measures included this comparison where electric heating was installed in the property (see the various electricity related improvement measures in Appendix 2 for more detail).

SAP or RdSAP?

6.36 Can full SAP be used (by assessors) instead of RdSAP? Can the EPC register 'take' full SAP EPCs?

6.37 Lodging EPCs for existing dwellings using SAP software has been possible in Scotland since 2013. However, for an assessor to lodge an EPC with SAP software they will need to have access to this software. This access will probably necessitate the RdSAP assessor acquiring additional competencies from a membership organisation to qualify as an assessor of new build dwellings from plans (known as an On Construction Dwelling Energy Assessor (OCDEA)).

Consistency of SAP / RdSAP ratings over time

6.38 As SAP and RdSAP evolve, e.g. as fuel prices, default 'u-values' change, will the impact of measures affect the resultant SAP rating differently?

6.39 The fuel prices that SAP and RdSAP reference within the PCDF are constantly evolving (see Appendix 7). The default U-values have had minor amendments applied to some levels of loft insulation in RdSAP for the first time, as opposed to additional defaults being added (which has happened at every revision of RdSAP). New tariffs governing certain types of wet central heating systems were added to RdSAP 2012. So yes, the SAP rating could vary between one version of RdSAP and the next.

6.40 The incorporation of party walls as a heat loss component within some dwelling types within RdSAP 2012 will have a major impact on some dwelling types, and no impact on others.

6.41 With each new version of SAP comes a basic relationship table to show the difference between one version and the other by fuel type. The relationship table for comparing SAP 2009 with SAP 2012 ratings is shown in Figure 6.6.

6.42 From the relationship table in Figure 6.7 it would appear that there is no difference between SAP 2009 and SAP 2012 ratings where gas heating is involved, and between 2 and 3 point decline where electric heating is involved. This table does not take account of changes such as the inclusion of party walls as a heat loss component that can reduce ratings by about 5 points (all other things being unchanged) or the introduction of the E18 hour tariff for electric wet systems that can increase the rating by over 20 points.

Figure 6.7: Table 15: Relationship between SAP 2009 and SAP 2012 ratings[72]

Where possible, SAP ratings previously calculated using SAP 2009 should be re-calculated using SAP 2012. The table indicates typical differences between the ratings.

SAP 2009	SAP 2012 for main heating fuel as:					
	Mains gas	LPG	Oil	Electricity	Solid mineral	Biomass
1	1	(-9)	(-11)	-3	(-5)	3
10	10	1	(-1)	6	5	12
20	20	12	10	16	15	22
30	30	23	21	27	26	32
40	40	34	32	37	36	42
50	50	45	43	47	47	51
60	60	56	54	58	57	61
70	70	67	65	68	67	71
80	80	78	76	78	78	81
90	90	89	87	89	88	91
100	100	100	98	99	99	100

Accuracy within SAP / RdSAP

6.43 Are there issues with accuracy when using EPCs or the SAP methodology to assess the energy performance of dwellings?

6.44 Approved SAP and RdSAP programs are accurate within defined error bars when assessing the energy performance of the dwelling, assuming the correct information is entered into the programs. A number of government policies are already using EPC bandings or SAP scores. Notwithstanding RdSAP's limitations discussed in this section, the Scottish Government took the decision that this tool is currently the best one available for taking forward REEPS.

Replicability of the results

6.45 Can an EPC assessor replicate the modelling in the field?

6.46 The REEPS modelling was not a theoretical exercise divorced from real dwellings. As the bases of all 355 archetypes were actual surveys of actual dwellings, then an EPC assessor should be able to collect the same data. SAP and RdSAP fundamentally use the same algorithms to calculate the SAP rating - so that if the same data is entered into the two programs they should produce the same results. While the results were modelled in a full SAP program, which may not be available to all EPC assessors, the RdSAP default U-values were used in the SAP modelling, for just this reason. A sample of 12 dwellings was modelled in both SAP and RdSAP to compare the results from the two programs with very similar results.

[72] Source: (2014) The Government's Standard Assessment Procedure for Energy Rating of Dwellings (2012 edition), p231, BRE, Garston

Specific technical Issues

6.47 The approach to identifying the poorer performing dwellings within the Scottish dwelling stock, by developing the initial typology and then the further segmentation into the 355 archetypes, was intended first to group properties with similar characteristics (i.e. heating system and wall construction). Secondly, to capture the diversity of dwellings within a typology grouping by further segmentation to include dwellings from the different SAP rating bandings and size. The improvement measures modelled within each archetype were tailored to the specific heating and insulation characteristics of individual archetypes (see Appendix 2 for a complete description of the improvement measures and when these measures were not modelled). Critical considerations included ensuring that every set of improvement measures was bespoke to the archetype, that all improvements modelled were technically feasible, and that all of the improvements could be modelled in SAP and RdSAP.

6.48 A variety of technical issues and concerns were raised in the discussions with the REEPS RAG during the lifetime of this project over the methodology and assumptions used in the modelling of the archetypes and the assumptions used in modelling the improvement measures. These concerns and issues are detailed below.

Traditional Buildings

6.49 Are traditional buildings fundamentally different than other dwellings? Are there aspects of traditional dwellings which could be different?

6.50 At one level, using the label 'traditional' is not at all helpful. It implies that there is also a 'non-traditional' group of dwellings, but there is no agreement or consensus about what forms of dwelling constructions or age bandings comprise these two groups. Conceptually, it is too imprecise. The development of the typology focussed on breaking the stock down to a much finer resolution than 'traditional'.

6.51 Accepting that 'traditional' is short hand for certain older construction types, there is an emerging and growing literature and experience with improving older dwellings and particular types of older constructions. Organisations such as Historic Scotland and others are conducting research and producing technical papers on just these issues[73]. What is emerging from this research is that it is possible to improve the energy efficiency of these dwellings and that, in principle, there is no need to preclude or exempt them from trying to achieve these higher standards for energy performance. That said, there are technical concerns with regards to the types of insulation materials being used and the techniques associated with their application that do need to be taken into consideration. These considerations may have cost implications for

[73] See for example: http://www.historic-scotland.gov.uk/index/heritage/technicalconservation /conservationpublications /technicalpapers.htm or http://sustainablereview.net/stba-decc-guidance-tools-retrofit-projects and https://www.gov.uk/government/policies/using-evidence-and-analysis-to-inform-energy-and-climate-change-policies/supporting-pages/research-economic-technical-social-and-trials

improvement measures. However, the improvement measure that gives rise to the biggest concerns – namely wall insulation in older stone and solid brick dwellings - was only needed in a small number of dwellings to achieve a higher EPC Band, and then usually only in achieving the biggest increase, namely improving dwellings in SAP banding G up to Band D.

Dealing with 'hard-to-treat' properties

6.52 Will the modelling identify appropriate measures to improve 'hard-to-treat' properties to enable them to achieve a higher EPC Band?

6.53 The report has already noted that this term is a misnomer, and one that is often wrongly applied, when the term that should be applied is 'expensive-to-treat'. Many of the wall types discussed previously under 'traditional' buildings (see section 6.49-6.51 above) would fall into this category, as would many non-traditional constructions, e.g. concrete constructions. These walls are being treated now, and have been treated for over 30 years. The insulation materials and the application techniques are known and available in the industry. Notwithstanding the discussion on technical issues regarding the suitability of certain insulation materials (see section 6.56-6.59 below), the issue is one of cost. They cost considerably more to insulate than filling a cavity wall. These higher costs were factored into the modelling of the archetype improvements. They are a major reason why many of the modelled improvement packages to meet the REEPS targets do not include solid wall insulation within them. Other measures or packages of measures to raise the energy rating standard within these properties were cheaper.

Dealing with Listed Buildings / Conservation Areas

6.54 How are listed buildings / conservation areas being dealt with in the REEPS modelling?

6.55 Listed buildings are not exempted from requiring an EPC[74]. Nor are dwellings within Conservation areas. However, they were not a specific concern of the modelling with regard to their improvement as the SHCS does not separately identify whether a dwelling is a listed building or not, or whether it is in a conservation area, or not, so fell outside of the modelling of improvements. Where dwellings fall into these categories, their status may restrict the measures that could be undertaken to improve the property, and may require negotiation with the local planners.

Condensation in buildings

6.56 Will installing insulation measures cause problems with dampness or interstitial condensation in buildings?

6.57 First, assuming that there are no other technical issues relating to the application of particular insulation materials, even technically suitable insulation has to be installed correctly. There are BSI standards, industry

[74] See Leaflet 01 of the EPC guidance, http://www.scotland.gov.uk/Topics/Built-Environment/Building/Building-standards/enerperfor/epcguidance for further details.

guidance, and good practice guidance available. The BRE published the report, 'Thermal Insulation: Avoiding Risks' many years ago and have updated and revised it since that explicitly dealt with such issues[75]. Over the last couple of years, the UK government has pushed the development of, and contractor compliance with, the PAS 2030 standards[76] . Yet many contractors still make elementary mistakes by blocking up necessary eaves ventilation in roof spaces, or putting cavity wall insulation into walls that should not be done, or do not draughtproof loft hatches when insulating lofts. Poor installation can cause serious problems.

6.58 A different issue is whether certain insulation materials are suitable to be used in certain types of properties, e.g. whether 'vapour closed' materials are suitable for insulating pre-1919 stone and solid brick walls, or whether only 'vapour open' materials should be used. Historic Scotland is carrying out research on these issues.

6.59 The modelling of insulation improvements to solid walls within the archetypes assigned a default U-value to the improvement. RdSAP makes no specific determination of the type of material used in insulating a solid wall, other than set out that the basis of the U-value improvement for solid wall insulation is 100mm of a material with a thermal conductivity of 0.04 W/mK. So this default improvement could be achieved by installing 100mm of mineral wool, or 100mm of sheep's wool, or 100mm of cellulose fibre insulation. Historic Scotland's research has shown that U-values of 0.35 W/m^{2}K can be achieved using 'vapour open' materials. The householder, designer or contractor prior to installation should carry out a technical assessment of the suitability of any insulation material for a given situation.

Default U-values and actual energy performance of dwellings

6.60 Are default U-values used in RdSAP markedly different from those measured 'in situ', which will have an impact on the assessment of the energy performance of a dwelling and the standards achieved through the improvements?

6.61 This issue goes well beyond the interests of REEPS, and affects all assessments of the energy performance of a dwelling. Again there is a growing literature arising from research projects suggesting that in-situ measurement of U-values are demonstrating differences with the defaults[77], but again that is nothing new. Thermal conductivity values are usually measured in the laboratory not 'in situ', and do not take account of the vagaries of the many things on site that could affect the actual U-value performance, therefore it should be expected that there will be differences.

[75] BRE (2002) Thermal Insulation: Avoiding Risks, 3rd edition, BRE, Garston was first published in 1989, updated in 1994 and revised again in 2002
[76] British Standards Institute (2014) PAS2030: 2014 edition: Improving the Energy Efficiency of Existing Dwellings: Specification for the installation process, process management and service provision, BSI
[77] See https://www.gov.uk/government/publications/in-situ-measurements-of-wall-u-values-in-english-housing

6.62 RdSAP is measuring the notional asset performance across the whole of the UK, thus the publication and use of the standard defaults. Should these defaults be changed every time a research project identifies a difference, because different reports show different degrees of variation? Should the results of small samples be extrapolated and applied across all dwellings? Statistical testing of the validity of these research findings would require much larger sample sizes. As noted above however, RdSAP and the use of defaults evolved to deal in part with the issue of the cost of the survey. In-situ measurements of U-values are not cheap, but where they are undertaken, there is nothing in RdSAP to prevent the default U-values being over-written. Where measured U-values are better than the defaults, there would be an improvement in the energy performance of the dwelling, making it less onerous to meet any subsequently defined REEPS standard.

Indoor air quality

6.63 Will setting a standard in REEPS affect indoor air quality by increasing the air-tightness of the dwelling?

6.64 Air quality is likely to become an issue as properties become more air tight. The building regulations are effectively pushing dwellings towards requiring mechanical ventilation as they increase the degree of air tightness assumed in the compliance calculations.

6.65 Within the improvements modelled, the only ones that had explicit implications for increasing air tightness were the draught proofing of windows and doors, and the installation of double (including secondary) glazing or triple glazing where single glazing existed. To meet the modelled REEPS standards, changing from single to double was only included as a measure in a small number of dwellings. By contrast, the draught proofing of windows and doors (and this was usually just the door as the majority of dwellings were double glazed throughout) was a more common recommended improvement. Past research has shown that draught proofing is very effective at reducing draughts that are most noticeable by household occupants, but only affects about 10% of the overall air infiltration rate within existing dwellings, as much of the air infiltration is coming through sources other than the windows and doors. That said, there are many sources of good/recommended practice that note that draught proofing of windows in kitchens and bathrooms should take into consideration other forms of ventilation to avoid problems with condensation.

6.66 Equally, it may improve the air quality where properties were otherwise cold. Other insulation improvements could have an indirect consequence for the air change rate within the dwelling, e.g. floor insulation beneath a suspended timber floor will effectively reduce air infiltration through this pathway; external cladding of a dwelling may block up unintended air infiltration pathways. Insulation should not be applied in such a way as to restrict intended ventilation pathways, i.e. air bricks or extract fans.

Boiler Oversizing

6.67 Will improved energy efficiency lead to existing boilers now being over-sized?

6.68 In practice, possibly: in theory, no. Where significant amounts of insulation are added to the dwelling then the existing boiler may be oversized given the revised heat load from the dwelling. Historically, in older, pre-1998 boilers, this would have resulted in declining boiler efficiency. Since 1998, and the implementation of the EU's Boiler Efficiency Directive, the differences in boiler efficiencies between full load and 30% part load are limited to 3%, so increased insulation should only have a marginal effect in these situations.

6.69 However, within SAP and RdSAP this is not an issue, even when the boiler is specifically identified through the PCDF and therefore its output is known, SAP and RdSAP assume that that boiler is perfectly sized to meet the heat demand of the dwelling. SAP and RdSAP not only ignore oversizing, they also ignore under sizing (where the boiler is inadequate to meet the heat load of the dwelling).

6.70 SAP and RdSAP are not boiler sizing programs.

Biomass boiler efficiencies

6.71 Are higher biomass boiler efficiencies reflected in the modelling?

6.72 At one point in SAP and RdSAP the efficiencies that could be applied to biomass boilers were the default efficiencies from Table 4a of the SAP manual that limited them to between 63% and 65%. With the extension of the PCDF to include more than just gas, oil and LPG boilers, biomass boilers are included as an option. For biomass the efficiencies range between 78% and 87% and for wood log boilers, they range between 67% and 86% (see Figure 6.8a and 6.8b respectively).

Figure 6.8a: Sample of wood log boilers in PCDF with efficiencies

Search for a product

biomass ✕ Search | Build Query | OK | Cancel

	Index	Brand Name	Model Name	Model Qualifier	Fuel	Type	Boiler ID	Seasonal Efficiency
Select	700048	Highland Biomass Solutions	Bio-Flame	15	Wood Pellets Bulk	Soild Fuel Boiler		77.8
Select	700122	KWB Easyfire	EF 2 V 35		Wood Pellets Bulk	Soild Fuel Boiler		87.1
Select	700123	KWB Easyfire	EF2 S 35		Wood Pellets Bulk	Soild Fuel Boiler		87.1
Select	700124	KWB Easyfire	EF2 GS 35		Wood Pellets Bulk	Soild Fuel Boiler		87.1
Select	700125	KWB Easyfire	EF2 S 30		Wood Pellets Bulk	Soild Fuel Boiler		86.2
Select	700126	KWB Easyfire	EF2 GS 30		Wood Pellets Bulk	Soild Fuel Boiler		86.2
Select	700127	KWB Easyfire	EF2 V 30		Wood Pellets Bulk	Soild Fuel Boiler		86.2
Select	700128	KWB Easyfire	EF2 GS 25		Wood Pellets Bulk	Soild Fuel Boiler		85.4
Select	700129	KWB Easyfire	EF2 S 25		Wood Pellets Bulk	Soild Fuel Boiler		85.4
Select	700130	KWB Easyfire	EF2 V 25		Wood Pellets Bulk	Soild Fuel Boiler		85.4
Select	700131	KWB Easyfire	EF2 S 22		Wood Pellets Bulk	Soild Fuel Boiler		84.9
Select	700132	KWB Easyfire	EF2 GS 22		Wood Pellets Bulk	Soild Fuel Boiler		84.9

1 2

Figure 6.8b: Sample of wood log boilers in PCDF with efficiencies

Search for a product

wood logs ✕ Search Build Query OK Cancel

	Index	Brand Name	Model Name	Model Qualifier	Fuel	Type	Boiler ID	Seasonal Efficiency
Select	700005	Aga	Much Wenlock		Wood Logs	Soild Fuel Boiler		70.4
Select	700021	Firebird	16" Inset Backboiler Stove		Wood Logs	Soild Fuel Boiler		67
Select	700023	Firebird	18" Inset Backboiler Stove		Wood Logs	Soild Fuel Boiler		68.7
Select	700026	Angus	Super 18kW		Wood Logs	Soild Fuel Boiler		80.3
Select	700027	Angus	Super 25kW		Wood Logs	Soild Fuel Boiler		80
Select	700028	Angus	Super 40kW		Wood Logs	Soild Fuel Boiler		80
Select	700029	Angus	Super 60kW		Wood Logs	Soild Fuel Boiler		77.7
Select	700030	Angus	Orligno 200 18kW		Wood Logs	Soild Fuel Boiler		81.4
Select	700031	Angus	Orligno 200 25kW		Wood Logs	Soild Fuel Boiler		81.4
Select	700033	Angus	Orligno 200 40kW		Wood Logs	Soild Fuel Boiler		80
Select	700034	Angus	Orligno 200 60kW		Wood Logs	Soild Fuel Boiler		77.7
Select	700088	ETA	SH 20		Wood Logs	Soild Fuel Boiler		85.6
1 2								

Rooms in the roof

6.73 How does SAP and RdSAP account for rooms in the roof?

6.74 Rooms in the roof are particularly problematic. They come in many different shapes / sizes / configurations - with and without dormers. RdSAP allows for a simple way of dealing with rooms in the roof by simply measuring the floor area. If an assessor adopts this approach it calculates the overall surface area of the room in the roof components from equations (that are set out in the SAP manual) and allocates areas to different components of the room in the roof using more equations. Alternatively, since RdSAP v9.91, RdSAP allows for all the individual components to be measured separately, and all of the individual U-values to be calculated and entered into RdSAP both for an existing dwelling and for one with any improvements. RdSAP does allow for the different elements of dormers to be surveyed and included in the assessment if the assessor chooses to measure them and then model them. However, on this matter the choice is left to the assessor, who will probably make the decision based on how much s/he is being paid to do the survey.

6.75 The nature of the improvements that are recommended by RdSAP are prescribed by the rules set out in Appendix T of the SAP manual, and a minimum requirement of raising the SAP score by at least 1 point. So with an uninsulated room in the roof, RdSAP will more than likely recommend room in the roof insulation as an improvement because it is within the Appendix T prescriptions and will raise the SAP score by more than a point. The recommendation will appear on the EPC. This recommendation is regardless of whether there are technical concerns or otherwise about doing the suitability of undertaking this insulation work. That is, unless the assessor suppresses the recommendation, which is within the control of the assessor, and then must provide reasons why this was done.

6.76 There is also a note on the EPC that householders should seek technical advice on the suitability of any of the recommendations before being carried out. This is no different with rooms in the roof than it is with cavity wall insulation, fitting heating systems.

6.77 More on the modelling of rooms in the roof within the archetypes is discussed in M3 in Appendix 2 of this report.

Improvement cost issues

Costs of improvement measures

6.78 On what are the improvement costs based? If they are not reflective of real life they will over or under-estimate the actual costs.

6.79 The costs used are not based on real life but on the mean indicative costs drawn from the PCDF (see Chapter 4). They are intended to be indicative rather than actual costs. The median dwelling within each grouping was chosen as the archetype, and as such, the costs are as likely to over-estimate as they are to over-estimate the actual costs for a particular dwelling. As these costs are then grossed up to reflect the national stock then over-estimating and under-estimating the costs should cancel out in in the overall statistics when costing improvements for an archetype.

6.80 Attempts were made to get 'real costs' by interviewing contractors, but these too produced a range of costs. More discussion on the approach to identifying costs of measures is set out in Appendix 3.

Additional Costs, including maintenance costs

6.81 What costs should be counted in modelling impact of works?

6.82 In discussions within the REEPS RAG, whatever costs were used for modelling, there were concerns that households in more rural areas and the island groups would have to pay additional costs likely to be incurred while installing certain measures for ancillary services or transport costs. The basis of the costs ultimately decided upon were the mean indicative costs within the PCDF that SAP and RdSAP use. The background to the PCDF costs was explored, and alternative costs were sourced from several contractors, and another source (see Appendix 3 for a fuller discussion on this). The decision was taken that maintenance costs were an issue for the householder or owner, and acknowledged that rural areas and the islands will face higher costs because of the market, but these were not specifically quantified.

Occupant related issues

Occupant behaviour and energy savings

6.83 Will the occupants' use of a property following improvements affect the actual levels of savings achieved?

6.84 Undoubtedly, yes. SAP and RdSAP are asset based ratings, that is, they are about the energy performance of what is installed in the dwelling, and these are modelled using standard assumptions about occupant behaviour. Occupant behaviour does not affect the SAP or RdSAP assessments of the dwelling because it is effectively controlled in the modelling. In reality, the biggest difference between varying energy consumption in dwellings is often related to how occupants use their dwellings. To ensure that householders understand how to take advantage of the energy efficiency improvements, and maximise the benefits, energy advice should be an integral part of any heating and insulation improvement programme.

Occupant behaviour and condensation

6.85 Will the occupants' use of a property following improvements create problems of condensation? Occupants' use of a property can cause problems with condensation before or after insulation or heating related improvements.

6.86 In principle improving the heating and improving the insulation standards within dwellings should reduce the risk of condensation occurring. However, condensation occurs when there is an imbalance in the equilibrium between heating, insulation and ventilation, so the occupants' use of the heating or approach to ventilation can effect this equilibrium, so condensation can occur. To minimise the risks of condensation occurring and to ensure householders understand how take advantage of the energy efficiency improvements, and maximise the benefits, energy advice should be an integral part of any heating and insulation improvement programme.

Miscellaneous issues

Emerging Technologies

6.87 How are emerging technologies accounted for in SAP and RdSAP?

6.88 SAP and RdSAP are continuously evolving methodologies (as discussed above in Sections 6.5 - 6.9). One impetus for this evolution is that new technologies emerge. Simply because a new product appears on the market does not mean it will be incorporated immediately into the SAP methodology. There are published protocols for testing new products, and SAP has the facility and defined conventions to include the impact of new technologies on the energy performance of a dwelling. RdSAP is not as flexible, and there is usually a time lag between agreeing the impact of a new technology into the SAP methodology and including it in RdSAP. RdSAP v9.92 saw the inclusion of high heat retention storage heaters and new waste water heat recovery systems, and new control devices and systems.

Embodied energy

6.89 As one of the aims of REEPS is to reduce carbon emissions by improving the energy efficiency of properties, will the embodied carbon content in these measures be assessed?

6.90 No. Embodied energy was considered outwith scope of Scottish Government policy of seeking to reduce emissions so not included in the modelling of the archetypes or their improvements.

Feed-in-tariffs and Renewable Heat Incentive

6.91 Are payments for feed-in-tariffs and the Renewable Heat Incentive (RHI) taken into account in the calculations on cost effectiveness of measures?

6.92 No. For the measures governed by the feed-in-tariffs (FiTs) (i.e. PVs and the 2 wind turbine options) a value for the generation from the specific technology was available because the same size system was installed in every case where it was modelled. However, the rates being paid out through the FiTs is constantly being revised, and usually downwards, so any value may be quickly out of date. For RHI technologies (various heat pumps and biomass boilers), the payments are related specifically to the individual dwelling and would be specific to each of the applicable technologies, and have eligibility rules, so were deemed to be outwith the scope of this modelling. A note has been inserted into each archetype document where these technologies were assessed pointing out the availability of FiTs and RHI and that these payments may make these technologies much more cost effective for the householder to install.

In-use factors

6.93 Were in-use factors taken into account within the modelling?

6.94 The two initial sample dwellings took in-use factors into account because they examined lifetime energy reductions and lifetime CO2e emission reductions. However, as the final decision was taken to model the packages on the basis of the cheapest cost to achieve the next EPC banding, it was not necessary to calculate the impact of the in-use factors.

Community heating

6.95 Were community heating and combined heat and power (CHP) taken into account in the improvement measures?

6.96 No. Community heating and CHP are valid interventions for certain properties in close proximity to one another. It was decided not to model them within the archetypes as an improvement measure because these options were deemed too site specific, and the actual systems are usually one-offs with individually calculated efficiencies.

Delivered Energy or Primary Energy

6.97 Did the modelling use delivered energy or primary energy in the modelling?

6.98 SAP and RdSAP calculate both delivered energy (i.e. amount of energy consumed in the home) and primary energy (i.e. the total amount of energy consumed by the nation, e.g. at the power station, to deliver the energy consumed in the home). It was decided to only present the delivered energy costs on the individual archetype documents as this related to what householders consumed in the dwelling.

Other Issues

6.99 Over and above all these issues, various individual factors were discussed that may have an impact on delivering on REEPS but fell outside the scope of this research project. These included the infestations of vermin and the presence of bats. These issues might affect the installation of improvement measures in individual situations, but were not accounted for in modelling archetypes. RdSAP and Green Deal assessors have the opportunity to ‘turn off’ recommendations arising from assessments of properties where local circumstances would prevent an improvement being carried out.

7 APPENDIX 1: SUMMARY OF THE SCOTTISH HOUSE CONDITION SURVEY (SHCS)

7.1 The Scottish House Condition Survey (SHCS), now part of the Scottish Household Survey (SHS), is a national survey of the housing stock, the only one of its kind in Scotland[78]. It is the largest single housing research project in Scotland, and the only national survey to link the physical condition of Scotland's homes to the experiences of householders. It does this by linking information gathered during a social interview with details from a physical inspection of properties conducted by a building surveyor.

7.2 The key objectives of the survey are:

- To monitor the physical quality of Scotland's housing stock at a national level over time.
- To contribute to the understanding of the factors which influence the physical condition of the housing stock.
- To provide a benchmark against which outputs from local house condition surveys and administrative data can be assessed.
- To help guide resource allocation within the Scottish Government.
- To explore relationships between investment and stock condition both at an individual local authority level and at the national level.
- To provide an information resource that can be used for policy development in all areas of housing.

7.3 At the core of the SHCS is the requirement to provide robust estimates of the condition and energy efficiency of Scotland’s residential housing stock. This has been constant since its inception and the survey continues to provide the national indicators for these topics.

7.4 Originally, the SHCS was conducted roughly every five years. MORI carried out the first SHCS in 1991, the second in 1996, and the third in 2002. In 2004, the Scottish House Condition Survey became a continuous survey, with fieldwork being conducted all year and every year. Between 2003 and 2006 the Office of National Statistics undertook the fieldwork. Since 2007, Ipsos MORI has carried out the survey.

7.5 In 2009, the SHCS was designated as a National Statistics product by the UK Statistics Authority (UKSA) demonstrating that SHCS statistics are accurate, trustworthy and compliant with the high standards required of National Statistics.

7.6 The survey has evolved since 1991, with regard to its scope, coverage and methodology. Following the review of the large scale Scottish population surveys, the SHCS was incorporated within the SHS and became one of its

[78] See http://www.gov.scot/Topics/Statistics/SHCS for further details

modules in 2012. Data from the survey is still reported under the name the Scottish House Condition Survey (SHCS).

7.7 The survey fieldwork aims to achieve around 3,000 paired interviews every year - a completed social survey interview with a full physical survey - nationally and 9,000 over the course of a 3 year period. The survey is based on a Scotland-wide random pre-selected sample, with no element of clustering. First, an interviewer conducts a social interview with a householder at the end of which an appointment is made for a surveyor to call to conduct a visual inspection of the property. The inspection of the property takes up to an hour, and covers both the external and internal parts of the dwelling. The data from both the social interview and the physical inspections are fully cleaned and validated.

7.8 Estimating energy use in dwellings is at the core of assessing the energy efficiency of the housing stock, the greenhouse gas emissions for which it is responsible and the risk of fuel poverty faced by residents. A number of measures produced through the SHCS are based on modelling energy use in the home:

- Energy Efficiency Ratings (SAP, EPC band, and NHER ratings),
- Environmental Impact Ratings,
- Carbon emissions estimate,
- and Fuel Poverty.

8 APPENDIX 2: METHODS, ASSUMPTIONS AND DEFAULT U-VALUES OF THE 38 MEASURES

8.1 This appendix describes the methods, assumptions and default U-values used in the modelling of the 38 improvement measures.

M1. Loft insulation, including top up

8.2 The starting point for the loft insulation was taken as thickness of the insulation identified by the SHCS, which was then converted to a U-value as per Table S9 in Appendix S of the SAP 2012 manual. Where there was no access to the loft, the U-value was taken from Table S10 of Appendix S (which effectively assumes that the amount of loft insulation is compliant with the Building Regulations prevailing when the dwelling was first constructed).

8.3 Where the thickness of the loft insulation was 150mm or less, it was assumed that it would be topped up to 300mm of mineral fibre quilt (or an equivalent material) being installed in part between the joists and in part cross laid over the joists. The default U-value for 300mm of loft insulation is 0.14 W/m^2K.

8.4 Where the existing loft insulation was more than 150mm, an upgrade to 300mm was only occasionally modelled.

8.5 Additional loft insulation was not recommended (as it was already present when more than 200mm of insulation was identified by the SHCS).

8.6 Not applicable: the dwelling does not have a pitched roof to insulate, e.g. ground and mid floor flats, and houses and bungalows with only flat roofs.

M2. Flat roof insulation

8.7 The starting point for the flat roof insulation was the SHCS identifying the roof structure of the main dwelling (occasionally) or an extension (more common) as a flat roof. Here, it would not be expected that the surveyor would be able to determine whether there was any insulation or not, so the U-value taken from Table S10 of Appendix S (which effectively assumes that the amount of flat roof insulation complies with the Building Regulations prevailing when the dwelling or the extension was constructed).

8.8 Where the flat roof was assumed to be uninsulated (i.e. with a U-value of 2.3 W/m^2K) it was assumed to be improved with 100mm of high density insulation board (i.e. with a thermal conductivity of 0.022) in a warm deck structure to achieve a U-value of 0.2 W/m^2K. This was a calculated U-value.

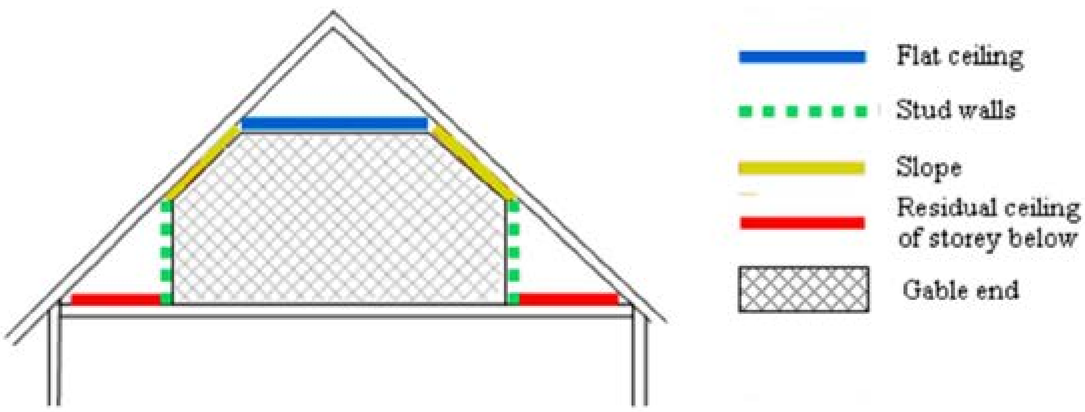
8.9 In most instances where flat roof insulation was modelled this was in an extension.

8.10 Not applicable: the dwelling does not have a flat roof to insulate, e.g. ground and mid floor flats, and houses and bungalows with only pitched roofs.

M3. Room in the Roof Insulation

8.11 Rooms in the roof come in different shapes, sizes and configurations, with and without dormers. What constitutes a room in the roof is defined in Section 3.3.5 of the SAP 2012 manual and Section S3.2 in Appendix S. RdSAP allows for a simple method of dealing with a dwelling with rooms in the roof by simply measuring the floor area, and letting RdSAP calculate the separate components of the room in the roof (i.e. the flat ceiling, the slopes, the stud walls, the gable walls, and the residual roof area for the main dwelling – Figure A2.1 below) by equations set out in Section S3.9 of Appendix S.

Figure A2.1: Components of Room in the roof



8.12 The U-values that RdSAP assign the individual components of the room in the roof are determined by the age of the room in the roof and the presence of any insulation. The default U-values are set out in Tables S9 and S10 of Appendix S (i.e. the same tables that define the default U-values for roof insulation). So a room in the roof (built before 1965) with no insulation seen during the SHCS survey, or where there is no access to allow the insulation to be assessed, would have a U-value of 2.3 W/m^{2}K assigned to all of the individual components of the room. These U-values would improve in dwellings built later. Where insulation levels of the individual components can be determined then this insulation can be accommodated in RdSAP.

8.13 The basis of the room in the roof formula (i.e. a rectangular room-in-roof area of average height 2.2m) is defined in Section S3.9 of Appendix S. Further guidance is provided in the separate RdSAP Conventions document. Where a room in the roof deviates significantly from this model (e.g. with dormers comprising more than 20% of the roof area) RdSAP allows for the individual components to be measured separately and included in the RdSAP assessment.

8.14 The SHCS follows the simple RdSAP method for dealing with rooms in the roof by collecting the floor area of the room in the roof, though it also collects the storey height.

8.15 As the archetypes were modelled in SAP 2012, the areas and U-values of the individual components of the room in the roof had to be entered separately into the SAP program. These were obtained by entering the room in the roof floor area into an RdSAP 2009 v9.91 program and recording the respective areas and U-values of the individual components derived by the RdSAP program and then entering these values into the SAP 2012 program. The gable wall of the room in the roof U-value was adjusted to match the U-value of the main dwelling walls. The flat ceiling of the room in the roof was assumed to be insulated to the standard of the residual ceiling of the storey below.

8.16 For improvements to the individual components of the room in the roof, it was assumed that at least 100mm of insulation was added to the slopes, stud walls and gable wall components of the room in the roof, and the insulation of the flat ceiling was increased to 300mm. RdSAP would assume that all of this insulation had a thermal conductivity of 0.04 W/mK, with the resultant U-values in the previously uninsulated rooms in the roof built before 1965 of 0.14 W/m^{2}K being achieved in the flat ceiling, and 0.40 W/m^{2}K being achieved in the stud walls, slopes and gable walls.

8.17 The modelling also assumed that where room in the roof insulation was being carried out that the loft insulation in the residual loft area was insulated as well as part of the job.

8.18 In deriving its default U-values for the insulation of the rooms in the roof, RdSAP does not distinguish between whether this insulation is added to the internal face of the room in the roof components, or if the insulation is added to roof void side of the component.

8.19 RdSAP, within its convention protocols, does allow assessors to double the thickness of the insulation recorded within an RdSAP assessment where high density insulation materials such as polyurethane (aka PUR) or polyisocyanuarte (aka PIR) insulation materials are used, and can be documented. So, notionally, the default U-value of 0.4 W/m^{2}K could also be achieved with 50mm of PIR or PUR insulation board being applied to the individual room in the roof components. If 100mm of such insulation material was installed, this would be recorded as having a thickness of 200mm in RdSAP 2012, and the default U-value from Table S9 of Appendix S would be 0.21 W/m^{2}K.

8.20 Not recommended: where the dwelling had a room in the roof, insulation was in dwellings constructed after 1991 (as the assumption being these spaces were insulated already).

8.21 Not applicable: dwelling does not have a room in the roof.

M4. Cavity Wall insulation

8.22 The starting point was taken as the SHCS survey identifying the dwelling as having a masonry wall with a cavity that showed no indication of having been insulated. The SAP default U-value for such a wall is determined by the age of the construction, and set out in Table S7 of Appendix S (see the row ‘Cavity as built’). For the largest percentage of dwellings with unfilled cavities (built between the 1920s and 1975) the default U-value would 1.6 W/m^{2}K. Later age bands have a lower starting U-value, reflecting the impact of the Scottish Building Regulations.

8.23 Where cavity wall insulation was assessed, the improved U-value was again taken from Table S7, but from the row ‘Filled cavity’. Where the starting point was 1.6, this would improve the U-value to 0.5 W/m^{2}K. Later age bands would achieve a slightly lower U-value.

8.24 The party walls were not assumed to be insulated as part of any of the improvement measures.

8.25 It is possible that the default U-values for cavity wall insulation will underestimate the potential impact of this improvement measure, as the defaults are based on a 50mm cavity being filled with blown fibre with a thermal conductivity of 0.04 W/mK. Many cavities in Scotland are wider than 50mm so more insulation could be injected into them. Secondly, many installers are beginning to use bead materials with a lower thermal conductivity (e.g. silver bead with a thermal conductivity of 0.032 W/mK). Using a U-value calculator, insulating a cavity wall with a 50mm cavity with blown fibre material with a thermal conductivity of 0.04 W/mK would achieve a U-value of 0.58 W/m2K, while the same wall being insulated with 70mm of silver bead would achieve a U-value of 0.38 W/m^{2}K. In such circumstances, RdSAP would expect the U-values to be calculated and the defaults to be over-written.

8.26 There are a number of stone wall archetypes where cavity wall insulation was assessed as an improvement option, not because the modelling assumed the stone walls were being filled, but because the dwellings had extensions with cavity walls that were surveyed as being not insulated.

8.27 Not recommended: if there was a cavity wall construction that was identified as being uninsulated then cavity wall insulation was always assessed.

8.28 Not applicable: no cavity wall.

M5. Solid Wall insulation

8.29 The starting point was taken as the SHCS survey identifying the wall construction as sandstone, granite, whinstone, solid brick or system built, and that there was no cavity within the wall construction. Such walls would need insulation applied to either the external face or the internal surface if their thermal performance was to be improved. The default U-values would be dependent on the age of the dwelling and the wall construction, as set out in Table S7 of Appendix S. With sandstone, granite and solid brick walls, the U-value is adjusted if an internal air gap is present (e.g. lathes and plaster or plasterboard on battens or dabs). The U-value for uninsulated pre -1976 sandstone and granite walls are further adjusted for the thickness of the wall (according to equations set out in Section S5.1.1 of Appendix S).

8.30 Where these walls had no insulation added already (some did, and were identified as ‘already present’), it was assumed that 100mm of wall insulation was added to the external wall. In RdSAP, the application of 100mm of wall insulation produces a default U-value of 0.35 W/m^2K with pre-1976 sandstone, granite, solid brick and system built walls (see Table S7 of Appendix S) regardless of whether the insulation is applied to the internal or external surface of the wall. The default U-value of 0.35 W/m^2K was used in the modelling of solid wall insulation where it was assessed as an improvement measure for an archetype.

8.31 RdSAP makes no specific determination on the type of material used in insulating a solid wall, other than set out that the basis of the default U-value improvement for solid wall insulation is 100mm of a material with a thermal conductivity of 0.04 W/mK. So this default improvement could be achieved by installing 100mm of mineral wool, or 100mm of sheep’s wool, or 100mm of cellulose fibre insulation.

8.32 RdSAP, within its convention protocols, does allow assessors to double the thickness of the insulation recorded within an RdSAP assessment where high density insulation materials such as polyurethane (aka PUR) or polyisocyanuarte (aka PIR) insulation materials are used, and can be documented. So, notionally, the default U-value of 0.35 W/m^2K could also be achieved with 50mm of PIR or PUR insulation board. If 100mm of such insulation was installed, it would be recorded as having a thickness of 200mm in RdSAP 2012, and the default U-value would be reduced to 0.18 W/m^2K.

8.33 RdSAP also makes no determination on whether the insulation installed needs to be ‘vapour open’ or ‘vapour closed’.

8.34 Not recommended: From the information available to the modelling exercise there was no reason to not recommend solid wall insulation where the dwelling was constructed of one of these wall types and it was not already insulated. Contraindications to not carrying out solid wall insulation would need to be identified onsite.

8.35 Not applicable: the dwelling was not constructed from one of the solid wall constructions.

M6. Floor Insulation

8.36 The starting point was taken as the SHCS survey identifying the floor construction and the presence of any insulation. In RdSAP, the calculation of the floor U-value also takes account of the exposed perimeter to floor area ratio of the heat loss ground floor. Each existing heat loss floor U-value was calculated individually by putting these details into an RdSAP 2009 v9.91 program, and the resultant U-value noted.

8.37 For the improvement measure, only dwellings with uninsulated heat loss ground floors were assessed (so upper floor flats were not assessed, nor were exposed floor areas over passageways in mid-terrace dwellings).

8.38 For an uninsulated suspended timber floor, it was assumed that 100mm of insulation quilt was fitted between the joists below the floor and suspended on netting.

8.39 For solid floors, it was assumed that 50mm of insulation with a hard finish was fitted on top of the existing solid floor.

8.40 RdSAP assumes the insulation to have a thermal conductivity of 0.4W/mK. Each U-value resulting from the addition of the floor insulation was re-calculated in RdSAP, and then entered into the full SAP assessment.

8.41 Not recommended: from the information available to the modelling exercise there was no reason to not recommend floor insulation where the dwelling had a heat loss ground floor and it was not insulated. If it was insulated this was recorded as ‘already present’.

8.42 Not applicable: only where there was no heat loss ground floor present: mid and top floor flats.

M7. Double Glazing to a U-value of at least 1.8 W/m^{2}K; M8. Secondary Glazing to a U-value of 2.4 W/m^{2}K; and M9 Triple Glazing to a U-value of at least 1.4 W/m^{2}K

8.43 The extent of multiple glazing within a dwelling, and the type of multiple glazing (see Table S14 of Appendix S) is assessed during the SHCS. The frame type is also assessed in the SHCS which has implications in full SAP but has been ignored in RdSAP until RdSAP v9.92 was introduced in December 2014.

8.44 Where the dwelling had single glazing, then all three multiple glazing options were assessed. The U-value of 2.4 W/m^{2}K for secondary glazing is the RdSAP default.

8.45 The double glazing U-value of 1.8 W/m^{2}K comes from Table 6e of the SAP manual and notionally represents a wood or uPVC-framed double glazed unit with a 16mm gap and soft coat low-emissivity coating, and is argon filled. Other double glazing permutations exist in Table 6e that would achieve the same U-value.

8.46 The triple glazing U-value of 1.4 W/m^{2}K also comes from Table 6e of the SAP manual, and notionally represents a uPVC or wood framed triple glazed unit with a 16mm gap and soft coat low-emissivity coating, and is argon filled. Again, other triple glazing permutations exist in Table 6e that would achieve the same U-value.

8.47 RdSAP conventions allow for the U-values from Table 6e of the SAP manual to be used in the program, and are not just limited to those in Table S14 in Appendix S.

8.48 Better performing glazing units exist in both Table 6e and on the open market.

8.49 If the dwelling had uPVC or wood framed pre-2003 double glazing already, then only the triple glazing option was assessed.

8.50 If the dwelling had pre-2003, metal frame double glazing, which in full SAP has a higher U-value than the RdSAP default of 3.1 W/m^{2}K for double glazing, then double and triple glazing were assessed as improvement options.

8.51 Not recommended: if the dwelling had post-2002 double glazing, then no alternative glazing measure was assessed. The small improvement in the U-value would have made this a very expensive option for a very small gain, if any gain at all, in the SAP score.

8.52 From the information available to the modelling exercise there was no reason to not recommend secondary, double or triple glazing as appropriate. However, these options may not be available for dwellings in conservation areas or in listed buildings. The SHCS does not collect that information about the property.

8.53 Not applicable: not an option here. Assessing the measure as an improvement, or recording it as not recommended or already present covered all of the options.

M10. Insulated External Doors

8.54 All external doors were assumed to be uninsulated solid wood external doors with a default U-value of 3.0 W/m^{2}K. The SHCS does not collect specifically this data item, therefore under RdSAP conventions, unless documentation is available to the contrary, then surveyors are to assume that the doors are not insulated. A house was assumed to have 2 external doors; a flat was assumed to have 1 external door and located in the unheated corridor wall (if this was present in the flat). These are the RdSAP defaults prior to doors being counted in RdSAP v9.91 (i.e. after October 2012).

8.55 Insulated doors were assumed to achieve a U-value of 1.0 W/m^{2}K. In RdSAP, if insulated doors are included then the U-value must be entered into the program.

8.56 Insulated doors were assessed in all instances.

M11. Hot Water Tank Jacket 80mm

8.57 The SHCS collects data on the type of insulation (spray foam or jacket) and its thickness on a dwelling's hot water cylinder. Where there was no access to the hot water cylinder, then the RdSAP defaults were used. These are set out in Table S17 and Table S18 of the SAP 2012 manual, and are dependent upon the installed heating and the age of the property

8.58 Where the hot water cylinder was uninsulated, then an 80mm jacket was modelled.

8.59 Where the existing cylinder insulation was a jacket of 50mm or less, an additional 80mm jacket was added on top of the existing jacket.

8.60 Where the existing cylinder was 40mm of spray foam or less, an additional 80mm jacket was added over the existing spray foam. This is modelled in RdSAP by increasing the thickness of the spray foam by half the thickness of the insulating jacket (i.e. by increasing the thickness of the spray foam by 40mm) as spray foam is considered twice as effective at retaining heat as a jacket.

8.61 Not recommended: from the information available to the modelling exercise there was no reason to not recommend insulation of the hot water tank where it was present and not already insulated as set out above. If it was insulated as not above, then it was recorded as already present.

8.62 Not applicable: given the prevalence of combi boilers within the Scottish dwelling stock, this was a common occurrence within the data set.

M12. Draughtproof Windows and Doors

8.63 The SHCS data set does not include information on whether windows and doors are draughtproofed as this item was only introduced into RdSAP in Scotland with version 9.91 from October 2012, i.e. after the current SHCS survey form had been designed. So the RdSAP 2009 v9.90 assumptions were used in the modelling of the archetypes – if the windows are double glazed then the assumption is that they are draughtproofed; if they are single glazed then the assumption is that they are not draughtproofed (with the exception of post-1991 dwellings with single glazing as the Building Regulations would have required them to be draughtproofed).

8.64 Doors were assumed not to be draughtproofed unless a dwelling was built post-1991, or the dwelling had post-2002 double glazing fitted on the assumption that the household upgraded the door at the same time. This would be recorded as ‘already present’.

8.65 While this measure was commonly applied within the modelling of the archetypes, it often only applied to the draught proofing of the doors, so in houses, 2 doors; in flats, 1 door, and therefore of limited impact. Where the windows in these houses were surveyed as having double or triple glazing of any type, they were recorded as being draught proofed.

8.66 Not recommended: from the information available to the modelling exercise there was no reason to not recommend the draught proofing of doors and single glazed windows. Within listed buildings, the draught proofing of windows may be restricted.

8.67 Not applicable: not an option here: either draught proofing was already present or it was modelled.

M13. Fit Baffle / Damper to open fire

8.68 The SHCS records the number of open fireplaces in a dwelling, as does RdSAP, which has an effect of increasing the dwelling’s ventilation rate: the more open fireplaces, the greater the increase in the ventilation rate, and thus the greater the calculated energy consumption.

8.69 Fitting a baffle / damper (a device for closing down the chimney when the open fire is not being used, thus reducing the air infiltration via the chimney) to the open fireplace reduces the ventilation losses (in full SAP, this is done by converting the open fireplace to a flue, and in RdSAP, by reducing the count of open fireplaces).

8.70 Fitting a baffle / damper to the open fireplace does not reduce its usability as an open fire.

8.71 Not recommended: from the information available to the modelling exercise there was no reason to not recommend fitting a baffle / damper to an open fire if an ope fire place was present and did not have a baffle / damper already fitted. It would not be possible to identify ‘already present’ from the data, as the RdSAP conventions and SHCS guidelines to surveyors deem open fireplaces with a damper to be recorded as a flue.

8.72 Not applicable: there were no open fireplaces in the property.

M14. Replace gas boiler with 88% efficient condensing boiler

8.73 For this option to be modelled the dwelling must have already had a non-condensing gas boiler central heating system installed, whether it be a regular boiler, combi boiler, or a back boiler.

8.74 The assumption here was that this improvement was a boiler only replacement, with respectively a condensing regular, combi or back boiler with a minimum SAP 2009 efficiency of 88% being installed. For the condensing back boiler, the actual efficiency used was 88.8% (i.e. the SAP 2009 efficiency for the Baxi BBU 15HE, the only condensing gas back boiler on the market known to the contractor).

8.75 Not recommended: should not be an option. If there was an existing condensing boiler within the dwelling, then it was recorded as ’already present’.

8.76 Not applicable: no gas boiler present.

M15. Replace oil / LPG boiler with 90% efficient condensing boiler

8.77 For this option to be modelled the dwelling must have already had a non-condensing oil or LPG boiler central heating system installed, whether it be a regular boiler or combi boiler.

8.78 LPG boilers can achieve a higher efficiency than mains gas boilers, thus were included in this option rather than in improvement M14.

8.79 The assumption here was that this improvement was a boiler only replacement, with respectively a condensing regular or combi or back boiler with a minimum SAP 2009 efficiency of 90% being installed.

8.80 Not recommended: should not be an option. If there was an existing oil or LPG condensing boiler within the dwelling, then it was recorded as ’already present’.

8.81 Not applicable: no oil or LPG boiler present.

M16. Full Gas Central Heating System including controls

8.82 Where the dwelling does not already have a central heating system, but has a mains gas meter, this improvement includes for fitting a mains gas condensing combi boiler with a SAP 2009 efficiency of at least 88% and a radiator system. The controls include for a programmer, room thermostat and thermostatic radiator valves (TRVs) to be fitted as well.

8.83 An example of a mains gas regular boiler that meets this criterion is the Hoval Top Gas 35 boiler, identified through the Product Characteristic Database, reference number 017241.

8.84 An example of a mains gas combi boiler that meets this criterion is the Sime Planet Dewey 90 boiler, identified through the Product Characteristic Database, reference number 008605.

8.85 There are other boilers within the Product Characteristic Database that meet this criterion, or have a higher efficiency.

8.86 Not recommended: should not be an option. If there was an existing condensing boiler within the dwelling, then it was recorded as ’already present’.

8.87 Not applicable: no gas central heating and no gas meter present.

M17. Full Oil or LPG Central Heating System including controls

8.88 Where the dwelling does not already have a central heating system, and there is no mains gas meter, this improvement includes for fitting an oil or LPG condensing combi boiler with a SAP 2009 efficiency of at least 90% and a radiator system. The controls include for a programmer, room thermostat and thermostatic radiator valves (TRVs) to be fitted as well.

8.89 An example of an oil regular boiler that meets this criterion is the Aquaflame HE22 boiler, identified through the Product Characteristic Database, reference number 008386.

8.90 An example of an oil combi boiler that meets this criterion is the Grant Engineering Horizon Combi 26, identified through the Product Characteristic Database, reference number 017163.

8.91 An example of a LPG regular boiler that meets this criterion is the Viesmann Vitodens 100-W WB1C 30KW, identified through the Product Characteristic Database, reference number 017002.

8.92 An example of a LPG combi boiler that meets this criterion is the Valliant Ultracom 2 24cxi, identified through the Product Characteristic Database, reference number 016326.

8.93 There are other boilers within the Product Characteristic Database that meet this criterion, or have a higher efficiency.

8.94 Not recommended: should not be an option. If there was an existing condensing boiler within the dwelling, then it was recorded as 'already present'.

8.95 Not applicable: no central heating but a gas meter present.

M18. Full Biomass Central Heating System including controls

8.96 Where the dwelling does not already have a central heating system, there is no mains gas supply, and the household is already using solid fuel for their heating, this improvement includes for fitting a wood pellet boiler with a SAP 2009 efficiency of 88.4% and a radiator system. The controls include for a programmer, room thermostat and thermostatic radiator valves (TRVs) to be fitted as well.

8.97 An example of a boiler that meets this criterion is the Grant Engineering Spira 9-36 boiler, identified through the Product Characteristic Database, reference number 700019.

8.98 Not recommended: a biomass system was not assessed as an improvement where the dwelling type was a flat because of the storage needs associated with the wood pellets.

8.99 It was also not recommended where other non-solid fuel heating systems were already installed.

8.100 Not applicable: not an option here. The reasons for not assessing the installation of biomass heating system for every archetype were covered in para 8.98 'Not recommended' and para 8.99.

M19. Fan Electric Storage Heaters with Auto Charge Control

8.101 Where the dwelling already has old block electric storage heating, or more modern slimline electric storage heaters, this improvement assesses replacing them with the more responsive fan storage heaters. Rather than rely on manual charge control (that is, the householder predicting the following day's weather and adjusting the charge level every night) the dwelling is fitted with a weather compensation system. Alternatively in Scotland, they may connect to SSE's Total Heating Total Control tariff or ScottishPower's Weathercall system (both of which utilise dynamic radio-teleswitching to remotely vary the charge level in response to changes in the weather).

8.102 Not recommended: electric storage heating was not recommended where there was a gas or oil central heating system or a solid fuel / wood boiler system present as the change would significantly reduce the SAP rating.

8.103 Not applicable: not an option here. As all of the archetypes assessed were connected to the electricity grid, electric heating could be installed and therefore be assessed as an option. However, assessing the installation of electric heating was not assessed for every archetype for the reasons set out in para 8.102 'Not recommended'.

M20. Quantum Storage Heaters

8.104 'Quantum' is Dimplex's product name for the High Heat Retention Electric Storage Heaters that have been included in SAP 2012 and RdSAP 2012 for the first time. The claim is that they are 27% cheaper to run than comparable static storage heaters, and consume 22% less energy for achieving the same comfort conditions in the dwelling. They have in-built programmers and thermostats.

8.105 These storage heaters can only be selected in SAP 2012 and RdSAP 2012 via the Product Characteristic Database. Two other companies' high heat retention storage heaters are also listed (i.e. Creda and Heatstore) but they are also referred to as 'Quantum' heaters.

8.106 Not recommended: 'Quantum' storage heating was not recommended where there was a gas or oil central heating system or a solid fuel / wood boiler system present as the change would reduce the SAP rating.

8.107 Not applicable: not an option here. As all of the archetypes assessed were connected to the electricity grid, electric heating could be installed and therefore be assessed as an option. However, assessing the installation of electric heating was not assessed for every archetype for the reasons set out in para 8.106 'Not recommended'.

M21. Full Electric Radiator System including controls on an off-peak tariff

8.108 Effectively, direct acting room heaters with individual appliance thermostats coupled, importantly, with a programmer and possibly a room thermostat, with the electricity charged on a 10-hour cheap rate tariff. It is the connection to the off peak tariff that gives them an advantage over direct electric heating. The 10 hours of the cheap rate is usually broken up over 3 periods over the day.

8.109 Unlike electric storage heaters, these systems do not have a storage capacity, and there may be times during the day when they may run on the more expensive part of the electricity tariff if use is not well controlled by the programmer.

8.110 Not recommended: an electric radiator system was not recommended where there was a gas or oil central heating system or a solid fuel / wood boiler system present as the change would reduce the SAP rating. Also not recommended where there was already electric storage heating.

8.111 Not applicable: not an option here. As all of the archetypes assessed were connected to the electricity grid, electric heating could be installed and therefore be assessed as an option. However, assessing the installation of electric heating was not assessed for every archetype for the reasons set out in para 8.110 ‘Not recommended’.

M22. Air Source Heat Pump: Air to water with full zone control

8.112 Heat pumps extract heat from the environment and then through a process of compression and expansion pass this heat into the dwelling. The great attraction of heat pumps is that they draw their heat for free and therefore you are only paying for the pumps and compressors to drive the system, so that you can notionally get more energy out of the system (as heat output) than you pay for to run the system (i.e. if it is well designed). Heat pumps operate most efficiently when the source temperature is as high as possible and the heat distribution temperature is as low as possible.

8.113 Here, the heat source would be the air. As this heating system would be installed in an existing dwelling then the heat distribution would be via radiators, so the heat would be transferred to the water circulating through the radiators which has implications for reducing the performance of the systems.

8.114 The controls would enable different areas of the dwelling to be programmed for the heating to be used at different times and to achieve different temperatures.

8.115 Not recommended: an air source heat pump system was not recommended where there was a gas or oil central heating system or a solid fuel / wood boiler system present as the change would reduce the SAP rating. Also, this option was not recommended where there was already electric storage heating.

8.116 Not applicable: not an option here. As all of the archetypes assessed were connected to the electricity grid, electric heating could be installed and therefore be assessed as an option. However, assessing the installation of electric heating was not assessed for every archetype for the reasons set out in para 8.115 ‘Not recommended’.

M23. Ground Source Heat Pump: Ground to water with full zone control

8.117 An alternative form of heat pump to the air source heat pump set out in M22. Here, the heat source is the ground, with the heat being gathered via a vertical bore hole or via coils buried horizontally in the ground. The latter approach would require the dwelling to have the necessary land area surrounding the dwelling in which to bury sufficient lengths of the coils to extract enough heat.

8.118 Again, as this heating system would be installed in an existing dwelling then the heat distribution would be via radiators, so the heat would be transferred to the water circulating through the radiators which has implications for reducing the performance of the systems.

8.119 The controls would enable different areas of the dwelling to be programmed for the heating to be used at different times and to achieve different temperatures.

8.120 Not recommended: ground source heat pump systems were not recommended where there was a gas or oil central heating system or a solid fuel / wood boiler system present. They were also not recommended where there was already electric storage heating. It was not recommended in any obviously urban setting because of the land requirements needed to bury the heat collecting pipes. It was not recommended for flats.

8.121 Not applicable: not an option here. The reasons for not assessing the installation of ground source heat pump for every archetype were covered in para 8.120 'Not recommended'.

M24. Room Thermostat for the heating system

8.122 Where a dwelling does not have a room thermostat, SAP and RdSAP assume that the lack of room thermostat will contribute to the heating system not switching off when the dwelling is up to temperature, that is, the dwelling will over-heat. With a wet central heating system, the lack of the room thermostat is assumed to contribute to the boiler cycling. Fitting a room thermostat reduces the possibility of the dwelling overheating and possibly the boiler cycling.

8.123 The presence of a room thermostat not only reduces the energy consumed in heating the dwelling by reducing overheating of the dwelling, but in tandem with a cylinder thermostat (on an indirect hot water system) is also assumed by RdSAP to improve the overall boiler efficiency by reducing cycling by the boiler (the presence of both a room thermostat and a cylinder thermostat on a wet central heating system are deemed to interlock the boiler).

8.124 Not recommended: this should not be an option, as either there is a room thermostat with a wet central heating or warm air system, and some electric radiator systems, so 'already present', or it is not applicable.

8.125 Not applicable: where there was an electric storage heating system or room heaters as the main form of heating.

M25. Programmer for the heating system

8.126 Where the dwelling does not have a programmer (or a time clock) to control when the heating comes on and goes off, the use of the heating is controlled simply by an off-on switch. Fitting a programmer allows the hours of operation of the heating system to be better controlled.

8.127 Not recommended: this should not be an option, as either there is a room thermostat with a wet central heating or warm air system, and some electric radiator and wet central heating systems, so 'already present', or it is not applicable.

8.128 During the modelling it was found that in some solid fuel systems, fitting a programmer made no difference at all in the energy performance of the dwelling.

8.129 Not applicable: where there was an electric storage heating system or room heaters as the main form of heating.

M26. Thermostatic Radiator Valves (TRVs)

8.130 Unlike a room thermostat which gives a centralised control over the dwelling temperature and can shut the boiler down when the dwelling is up to temperature, TRVs control the temperatures in individual rooms, and only shut down individual radiators. Fitting TRVs provide better control of temperature across the whole dwelling.

8.131 If the dwelling does not have a wet central heating system, then TRVs would not be recommended.

8.132 Not applicable: where there was an electric storage heating system, warm air systems, or room heaters as the main form of heating.

M27. Full Controls Package (room thermostat, programmer and TRVs)

8.133 Where the dwelling has no controls at all on a wet central heating system, then this package of controls would be recommended.

8.134 Not recommended: where some of the controls are present, or the type of installed heating system does not require this full package of controls (e.g. a warm air system would not need TRVs to be fitted) those missing would be recommended as individual improvements via M24, M25 and M26 as appropriate.

8.135 Not applicable: where there was an electric storage heating system, warm air systems, or room heaters as the main form of heating.

M28. Auto Charge Control

8.136 This improvement would only be recommended for an existing electric storage heating system currently reliant upon manual charge control.

8.137 Not applicable: with all other forms of heating

M29. Solar Thermal 4m^2

8.138 Whether the dwelling has solar panels for hot water or not is one of the data items collected by the SHCS. Where the dwelling does not have solar panels, the surveyors record whether the dwelling is suitable for them to be fitted. The criteria they are given for this assessment are that the dwelling has 8m^2 of roof area facing within 30^o of south (which is assessed with a compass), and that they are not over-shaded by taller buildings. Where the SHCS assessment does not recommend fitting solar thermal panels, this improvement was not assessed.

8.139 Where the SHCS indicates that the dwelling is suitable, this improvement assessed fitting a 4m^2 (gross area) glazed flat plate collector, assuming a south orientation, at a 30^o roof pitch with average over shading. If the dwelling had a hot water cylinder, this was replaced with a 250 litre combined cylinder with 100 litres dedicated to solar heated water storage. This cylinder was assumed to be insulated with 50mm of spray foam.

8.140 If the dwelling did not have a hot water cylinder (e.g. where there was a combi boiler), then the solar thermal was assumed to have its own 100 litre store.

8.141 Not recommended: where SHCS indicated the dwelling was unsuitable for solar panels or already installed.

8.142 Not applicable: where the dwelling did not have its own roof, eg, ground and mid floor flats.

M30. Photovoltaic (PV) Panels – 2 kWp

8.143 Whether the dwelling has PV panels for generating electricity or not is one of the data items collected by the SHCS. Where the dwelling does not have PV panels, the surveyors record whether the dwelling is suitable for them to be fitted. The criteria they are given for this PV assessment are that the dwelling has 8m^2 of roof area facing within 45^o of south (which is assessed with a compass), and that they are not over-shaded by taller buildings. Where the SHCS assessment does not recommend fitting PV panels, this improvement was not assessed.

8.144 Where the SHCS indicates that the dwelling is suitable, this improvement assessed fitting a PV array with a rated output of 2 kWp, assuming a south orientation, at a 30^o roof pitch with average over shading.

8.145 Not recommended: where SHCS indicated the dwelling was unsuitable for PVs or they were already installed.

8.146 Not applicable: where the dwelling did not have its own roof, e.g, ground and mid floor flats.

M31. 2m Diameter Wind Turbine on Roof of Dwelling

8.147 As long as the dwelling had its own roof (so ground and mid floor flats were excluded from this assessment), a small wind turbine, that is one with a blade diameter of 2m with the hub sitting 2m above the apex of the roof was assessed. As the output from a wind turbine varies depending on its location, then each archetype was assigned an urban, suburban or rural designation within SAP 2012 based on its original local authority area.

8.148 Not applicable: where the dwelling did not have its own roof, eg, ground and mid floor flats.

M32. 5m Diameter Wind Turbine on Stand-alone Mast

8.149 A larger wind turbine, that is, one with a blade diameter of 5m with the hub sitting 5m above the ground on its own stand-alone mast was assessed. Such a mast needs to be sited at a safe distance from the dwelling so this improvement was not assessed for all dwelling types (e.g. not with flats) or in all areas. As the output from a wind turbine varies depending on its location, then each archetype was assigned an urban, suburban or rural designation within SAP 2012 based on its original local authority area.

8.150 Not recommended: given the space requirements this option was not recommended in obviously urban areas.

8.151 Not applicable: not an option here. The reasons for not assessing the installation of a stand-alone wind turbine for every archetype were covered in para 8.150 'Not recommended'.

M33. 100% Low Energy Lighting

8.152 The SHCS assesses the percentage of light fittings within a dwelling fitted with low energy lighting. If there was less than 100% already, this improvement increased the percentage to 100%. For the sake of costing the improvement it was assumed that there was one light fitting in each room.

8.153 If the dwelling did not have 100% low energy lighting then this measure was assessed.

8.154 Not recommended: should not be an option, as either all the fixed light fittings had low energy lights already, so 'already present' or the measure was assessed.

8.155 Not applicable: not an option here, as either low energy was recommended or cover by para 8.154 'Not recommended'.

M34. Cylinder thermostat on hot water cylinder

8.156 The SHCS notes whether a cylinder thermostat is fitted to an indirect hot water cylinder. A cylinder thermostat would not be needed for other types of hot water supply: combi boilers do not have a hot water cylinder, while in SAP and RdSAP, where the primary water heating is provided by means of an electric immersion heater, the cylinder thermostat is assumed to be built into the immersion heater.

8.157 The presence of a cylinder thermostat (on an indirect hot water system) not only reduces the energy consumed in heating the hot water but in tandem with a room thermostat is also assumed by RdSAP to improve the overall boiler efficiency by reducing cycling by the boiler (i.e. the presence of both a room thermostat and a cylinder thermostat on a wet central heating system are deemed to interlock the boiler).

8.158 Not recommended: this should not be an option, as either there is a cylinder thermostat, so ‘already present’, or the measure was assessed, or it was not applicable.

8.159 Not applicable: with combi boilers, and electric immersion heaters and community heating, as RdSAP assumes all of these types of water heating include control of the water temperature.

M35. Air to Air Heat Pump on E10 tariff with full zone control

8.160 Another alternative to the two heat pumps set out above in M22 and M23.

8.161 Here, the heat source is air, but there is no radiator system, as the heat distribution is also via warm air. This could conceivably be a centralised air source heat pump distributing warmed air around the dwelling via ducting. As this heating system would be installed in an existing dwelling then it may be more appropriate to fit individual units into each room. The advantage of an air to air heat pump delivering warm air directly into a room, compared to an air to water source heat pump circulating warmed water through the radiators, is the improved performance because the air temperature does not have to be raised as high as water temperature to pass heat to the occupants.

8.162 The controls would enable different areas of the dwelling to be programmed for the heating to be used at different times and to achieve different temperatures.

8.163 Not recommended: an air source heat pump system was not recommended where there was a gas or oil central heating system or a solid fuel / wood boiler system present as the change would reduce the SAP rating. Also not recommended where there was already electric storage heating.

8.164 Not applicable: not an option here. As all of the archetypes assessed were connected to the electricity grid, electric heating could be installed and therefore be assessed as an option. However, assessing the installation of electric heating was not assessed for every archetype for the reasons set out in the paragraph above.

M36. More Efficient Room Heater

8.165 A number of dwellings were identified as reliant on solid fuel open fires as secondary heating with 32% efficiency rating in SAP and RdSAP, or even worse, mains gas decorative fuel effect fires open to the chimney with a 20% efficiency rating.

8.166 This option assessed replacing a solid fuel, open fire with grate with a HETAS-approved solid fuel stove with a 65% efficiency rating or fitting a solid fuel cassette (effectively, an insert into the fire place that converts the open fireplace into a closed room heater[79] with the consequential improvement in the efficiency from 32% to 65%).

8.167 Where secondary room heater was the mains gas decorative fuel effect fire open to the chimney (with its 20% efficiency in SAP), the assumption was to replace it with a flush fitting fire sealed to the chimney with a 40% efficiency rating.

8.168 In a couple of dwellings with just one gas room heater, and portable electric heating became the primary or secondary (under SAP conventions where 25% or less of the habitable rooms have fixed room heaters, then portable electric heaters are to be modelled as primary heating; and where between 25% and 75% of the habitable rooms have fixed heating, then portable electric heating is to be modelled with direct electric as the secondary heating) adding additional gas fires to remove the portable electric heating from the assessment has significant benefits in SAP.

8.169 Not recommended: this should not be an option: where there was a solid fuel fire or gas coal effect fire open to the chimney the measure was assessed, or it was not applicable or 'already present'.

8.170 Not applicable: where the dwelling was not inadequately heated; where there was no solid fuel open fire; or where there was no gas or coal effect open to the chimney fire.

M37. Thermaflow Electric CPSU Boiler System

8.171 SAP 2012 and RdSAP 2012 now include an18-hour off peak tariff to assess electric combine primary storage unit (CPSU) wet central heating systems that were previously poorly rated because they were assessed on the wrong tariff. This tariff is only available in the Scottish Power supply area (i.e. Supply Area 18).

8.172 Where a dwelling was off the gas grid, without an existing central heating system, and its original local authority area was within the Scottish Power supply area, this option was assessed.

8.173 Not recommended: An electric wet central heating system was not recommended where there was a gas or oil central heating system or a solid fuel / wood boiler system present as the change would reduce the SAP rating. Also not recommended where there was already electric storage heating. Not recommended for areas falling outside Supply Area 18.

8.174 A few properties already had these systems installed, thus 'already present'

8.175 Not applicable: not an option here. As all of the archetypes assessed were connected to the electricity grid, electric heating could be installed and therefore be assessed as an option. However, assessing the installation of

[79] More information on solid fuel cassettes can be obtained from the web e.g. http://www.artisanfireplaces.co.uk/fires-and-fireplaces/solid-fuel-cassette-fires/

electric heating was not assessed for every archetype for the reasons set out in paragraph above.

M38. Tariff Switch

8.176 Both Scottish Power and SSE have available normal off-peak tariffs and 24-hour based tariffs for electric storage heating. Where a dwelling has an existing storage heating system, then the benefit of switching tariff was assessed. This tariff switch was only included in the improvements assessed if it resulted in an improvement in the SAP score of the dwelling.

8.177 There are also 10-hour off peak tariffs available for direct electric systems.

8.178 Not recommended: where after modelling the inclusion of the tariff switch for a type of electric heating the SAP rating went down.

8.179 Not applicable: where the heating was anything other than electric heating.

9 APPENDIX 3: COSTING IMPROVEMENT MEASURES

9.1 An element of the research was concerned with identifying the source and credibility of the costings of improvement measures quoted within RdSAP, and to explore their relationship with real world costings in Scotland.

9.2 The starting point for compiling a list of costs for the various improvement measures to be modelled against the 355 base case archetypes was the Product Characteristics Database File (PCDF). This PCDF is built into SAP and RdSAP software, and contains the costs that appear on EPCs and in Green Deal Advice Reports. Notionally, these costs are updated annually.

9.3 The PCDF does not contain a single cost per improvement measure but a range of costs (see Table A3.1). For most improvement measures, there is a low and a high cost figure given (see the Low Cost Range A and High Cost Range A columns in Table A3.1). There is one measure `with costs in the Low Cost B and High Cost B columns (i.e. New or replacement storage heaters). There are two improvement measures with only a single price in the Low Cost B column (i.e. low energy lighting and insulated doors). The difference between the A Columns and B columns is that the A column represents the cost per job; the B Columns represent a variable cost where the number of units to be installed in the dwelling is multiplied by this variable cost to get the total cost of that improvement measure.

9.4 Where an EPC recommends, for example, a 80mm hot water cylinder jacket, the cost of this improvement would appear as an indicative cost of between £15 and £30, with the low and high cost Column A figures representing lower and upper limits of the indicative cost range presented on the EPC (see Figure A3.1a). For storage heaters, the low and high cost Column B figures would be multiplied by the number of storage heaters to be installed, which in this dwelling was assessed to be 3, to produce an indicative cost range of between £900 and £1200 (see Figure A3.1a). Low energy lights improvement costs would appear as a single figure on the EPC. Figure A3.1b below shows the EPC costs for a dwelling that had 5 light fittings without low energy lamps (see Figure A3.1b).

Figure A3.1a: EPC Indicative range costs

Recommended measures		Indicative cost	Typical saving per year	Rating after improvement	
				Energy	Environment
1	Add additional 80 mm jacket to hot water cylinder	£15 - £30	£20	C 74	D 67
2	Fan assisted storage heaters and dual immersion cylinder	£900 - £1,200	£129	C 80	D 67

Figure A3.1b: EPC indicative range costs and single figure costs

Recommended measures		Indicative cost	Typical saving per year	Rating after improvement	
				Energy	Environment
1	Increase loft insulation to 270 mm	£100 - £350	£79	C 69	C 69
2	Add additional 80 mm jacket to hot water cylinder	£15 - £30	£24	C 70	C 71
3	Low energy lighting for all fixed outlets	£25	£27	C 72	C 72

Table A3.1: Improvement Measure costs within the PCDF

Improvement Measure	Low cost range A	Low cost B	High cost range A	High cost B	Mean cost
Loft insulation	100		350		225[80]
Cavity wall insulation	500		1,500		1,000
Hot water cylinder insulation	15		30		22.5
Draught proofing	80		120		100
Low energy lights		5			5
Cylinder thermostat	200		400		300
Heating controls for wet central heating system	350		450		400
Heating controls for warm air system	350		450		400
Upgrade boiler, same fuel	2,200		3,000		2,600
Biomass boiler	7,000		13,000		10,000
Biomass room heater with radiators	7,000		13,000		10,000
New or replacement storage heaters		300		400	350
Replacement warm-air unit	1,250		2,500		1,875
Solar water heating	4,000		6,000		5,000
Double glazing	3,300		6,500		4,900
Secondary glazing	1,000		1,500		1,250
Solid wall insulation	4,000		14,000		9,000
Condensing oil boiler	3,000		7,000		5,000
Change heating to condensing gas boiler	3,000		7,000		5,000
Photovoltaics	9,000		14,000		11,500
Wind turbine on roof	1,500		4,000		2,750
Flat roof insulation	850		1,500		1,175
Roof room insulation	1,500		2,700		2,100
Flue gas heat recovery	900				450
Floor insulation	800		1,200		1,000
Insulated doors		500			500
Waste water heat recovery	585		725		655
Biomass boiler	7,000		13,000		10,000
Solid wall insulation and cavity wall insulation	4,500		15,500		10,000
Air Source Heat Pump with radiators	6,000		10,000		8,000
Air Source Heat Pump with underfloor heating	6,000		10,000		8,000
Micro combined heat and power (co-generation)	5,500				5,500
Ground source heat pump with radiators	9,000		17,000		13,000
Ground source heat pump with underfloor heating	9,000		17,000		13,000
Triple glazing	5,000		10,000		7,500
Wind turbine separate mast	15,000		25,000		20,000

[80] As already noted, for loft insulation only, the mean cost was not used. Rather the low range cost (i.e. £100) was used in instances where the loft insulation top up was 100mm or less; the high range cost (i.e. £350) was used in instances where the loft insulation top up modelled was more than 100mm thick.

9.5 The mean cost (i.e. the last column in Table A3.1 above) was calculated as part of the research project and does not appear in the PCDF, nor is it used in SAP and RdSAP assessments.

9.6 An attempt was made by the contractors to track the PCDF insulation cost ranges back to a unit prices per m^2 (see the background note on this attempt at the end of this appendix).

9.7 As an additional check on the PCDF improvement costs, other costs were collated for the range of improvement measures from a variety of other sources, including:

- those used in a report by the Parity Projects[81] which was concerned with a similar area of research work in England;
- those obtained through interviewing three Scottish central belt contractors for doing improvement works on a one-off dwelling;
- an attempt to work out costs from scratch using a UK SPONS 2014 pricing guide for preparing tender costs[82];
- internet searches for costs for the new high heat retention (i.e. Quantum) electric storage heaters and for replacement heating appliances.

9.8 The collated results are set out in Table A3.2 below. Not all of the prices for all of the improvement options were available from every source.

Table A3.2: Assorted Cost of Improvement Measures

	PCDF mean cost £/job unless stated	**Parity Project Costs £/job unless stated**	**Contractor1 £/job unless stated**	**Contractor2 £/job unless stated**	**Contractor3 £/job unless stated**	**SPONS exercise £/job unless stated**	**Web search £/job unless stated**
Loft insulation from 0 to 300mm	£350 (High cost used)	£350	5.90/m^2 + 2.60/m^2 in rural Scotland		£6.50/m^2	£4/m^2	
Loft Insulation top up from 200 to 300mm	£100 (Low cost used	£300	3.80/m^2 + 2.60/m^2 in rural Scotland		£4.5/m^2	2.74/m^2	
Cavity wall insulation	£1,000	£300	3.60/m^2 per 50mm gap + 2.80/m^2 in rural Scotland; 5/m^2 per 85mm gap + 2.80/m^2 in rural Scotland		£5/m^2 (Bead)		
Hot water cylinder jacket insulation (80mm)	£22.5	£40	£20				
Draught proofing	£100	£50 + (fraction not	£40 + £18 per window unit (sash				

[81] Parity Projects (2014) *Analysis for WWF and UKGBC: achieving minimum EPC standards in housing*, version 1.4, 22 May 2014, Parity Projects, London
[82] Davis Langdon (2013) *SPONS Architects' and Builders' Price Book 2014*, Taylor Francis, Abingdon

		DP * £150)	counts as 2 units); £22 per door				
Low energy lights	£5 per bulb	£20 per bulb					
Fit Cylinder thermostat	£300	£300		£120			
Heating controls for wet central heating system full package	£400	£500		£200 for combined room thermostat and programmer			
Heating controls for wet central heating system part package		£280		£200 for combined room thermostat and programmer			
Fit Thermostatic Radiator Valves			£20 per TRV	If system drained £45 for first and £20 for rest. If system not drained £90 for first and £20 for rest			
Heating controls for warm air system	£400						
Upgrade combi boiler, mains gas	£2,600	£1,500	£1,650	£1,600			
Upgrade standard boiler, mains gas		£2,400	£1,650	£1,850			
Biomass boiler	£10,000						
Biomass room heater with boiler	£10,000						
New or replacement storage heaters	£350 per storage heater	£2,500					
New or replacement Quantum storage heaters							£700 per heater
Electric wet system (direct / CPSU / thermal store)		£4,000					
Replacement warm-air unit	£1,875						
Solar water heating	£5,000	£3,500 for 4m^2				£3,560 to £4,500 for 4m^2	
Double glazing low-e (u-value 2.1)	£4,900	£250/m^2	£350 per window (upvc)		120/m^2 standard and 270/m^2 fully reversible	£162/m^2	
A-rated Double Glazing low-e Argon (u- value 1.8)						£350/m^2	
Secondary glazing	£1,250		£45/m^2				
Solid wall insulation – internal wall insulation	£9,000	£55/m^2	£70/m^2 modern; £85/m^2 older home plus extras (+£5.80/m^2 in rural Scotland)	£50/m^2	£120/m^2	£23/m^2	
Solid wall insulation – external wall insulation	£9,000	£90/m^2	£80/m^2 plus extras + £5.80/m^2 in rural Scotland		100/m^2	£44/m^2 plus scaffold	

Condensing oil boiler and radiators	£5,000		£5,400				
Change heating to condensing gas condensing boiler and radiators	£5,000	£3,000	£3,200	£2,800		£55 to £77/m^2	
Photovoltaics	£11,500	£600 + £1,350/kWp				£4,409 to £5,454 per kWp	
Wind turbine on roof	£2,750						
Flat roof insulation	£1,175	£50/m^2					
Roof room insulation	£2,100		As internal wall insulation	£50/m^2			
Flue gas heat recovery	£450						
Floor insulation – below suspended timber floor	£1,000	£400 + £25/m^2	£16/m^2 + £2.60/m^2 in rural Scotland				
Floor insulation – above solid floor	£1,000	£400 + £30/m^2	£30/m^2+ £2.60/m^2 in rural Scotland			£20/m^2	
Insulated door	£500 per door	£900 per door			£370 per door		
Waste water heat recovery	£655	£300 + £350 per room installed					
Biomass boiler	£10,000						
External wall insulation + cavity fill insulation	£10,000						
Air Source Heat Pump with Radiators	£8,000	£7,500					
Air Source Heat Pump with underfloor heating	£8,000						
Micro co-generation (also known as micro CHP)	£5,500						
Ground Source Heat Pump with radiators	£13,000	£11,000					
Ground Source Heat Pump with underfloor heating	£13,000						
Triple glazing	£7,500	£370/m^2			£145/m^2 standard, £295/m^2 fully reversible		
Replacement LFE inset gas fire flued							£450
Solid fuel fire cassette							£450
New Hot Water Cylinder with 50mm Spray Foam		£750 per dwelling		£450			
Wind turbine separate mast	£20,000						

9.9 What emerges from Table A3.2 is that there is no one consistent cost for any of the improvement measures; the costs are not even presented in the same units. There was usually no explanation that accompanies the costs to elaborate on what is included or not included within them. It also became quite clear when interviewing the contractors that the costs of doing jobs in the Highlands and Islands and other rural areas would be higher still.

9.10 Among the three contractors there was a consensus that the cost of solid wall insulation, whether internally or externally applied, was determined 'by the details' – that is, how you deal with reveals around windows, the fitting of new sills, the treatment of satellite and telecommunication systems affixed to walls, the treatment of external gas and electricity meters, the treatment of existing vents, the external finish of the system, and the level of decoration to be done subsequently by the contractor. One contractor stated that if you included for everything in a single price then you would never win a contract. These things were usually identified as specified extras to the quoted per m^2 price.

9.11 One contractor specifically quantified some of these costs for working in the Highlands and Border areas of Scotland (which was deemed to be more than 1 hour drive time up to about 0.5 day drive from the central belt of Scotland), as they were working on contracts in those areas at the time of the interview. Additional rural costs ranged from a further 7%-8% for solid wall insulation; 9%-16% for floor insulation; 44% for loft insulation (and 68% for top up loft insulation); 56% or 78% for cavity wall insulation, depending on the gap to be filled. Working on the islands would be more again as ferry costs would also have to be then factored in.

9.12 Using the dimensional data from the 355 archetypes, the costs for various insulation improvements were calculated using the different contractor unit prices set out in Table A3.2 above. The distribution of the calculated job costs could then be compared with the indicative costs from the PCDF.

Loft Insulation Costs

9.13 In Figures A3.2 and A3.3, the range of costs for top up loft insulation (i.e. where there is some loft insulation already) and virgin loft insulation (i.e. where there is no loft insulation at all) are presented. For top-up loft insulation the calculated contractor costs ranged between £53 and £1598, while the virgin loft insulation costs ranged between £83 and £2120 (see Table A3.3).

Table A3.3: Loft Insulation Costs

	Top-up loft insulation	Virgin loft insulation
Number of instances (n)	624	624
Number > £350	181	358
Number <£100	6	2
% outside PCDF range	30%	58%
Mean cost	£306	£439
Median cost	£266	£384
Maximum cost	£1,598	£2,130
Minimum cost	£53	£83
Cost used in modelling	£350	£350

% difference between mean contractor and cost used in modelling	-12%	+25%

Figure A3.2: Range of top-up loft insulation costs calculated from 355 archetypes data

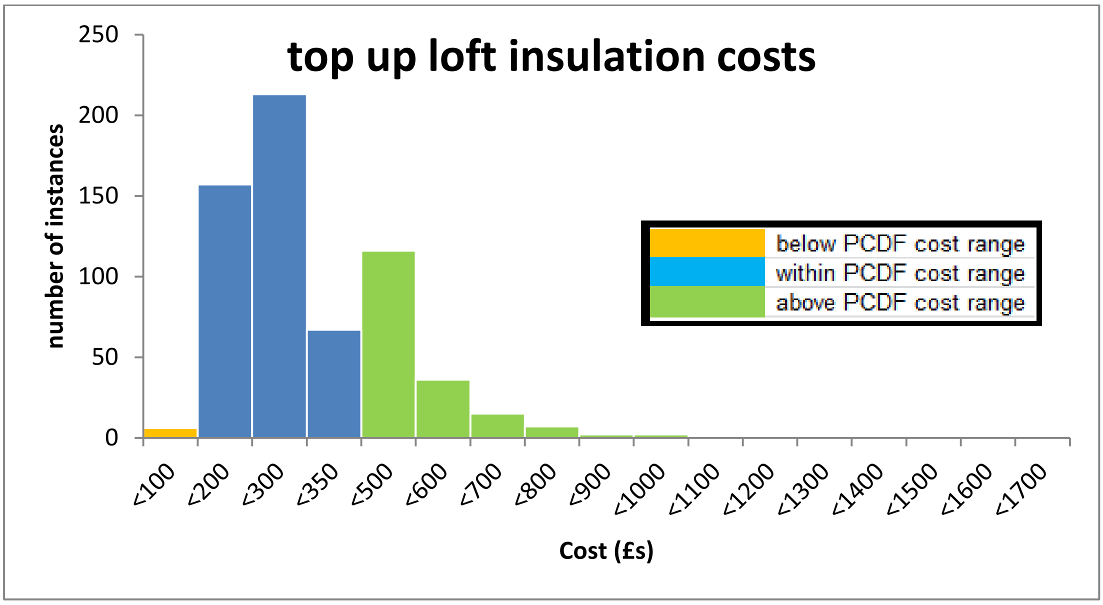
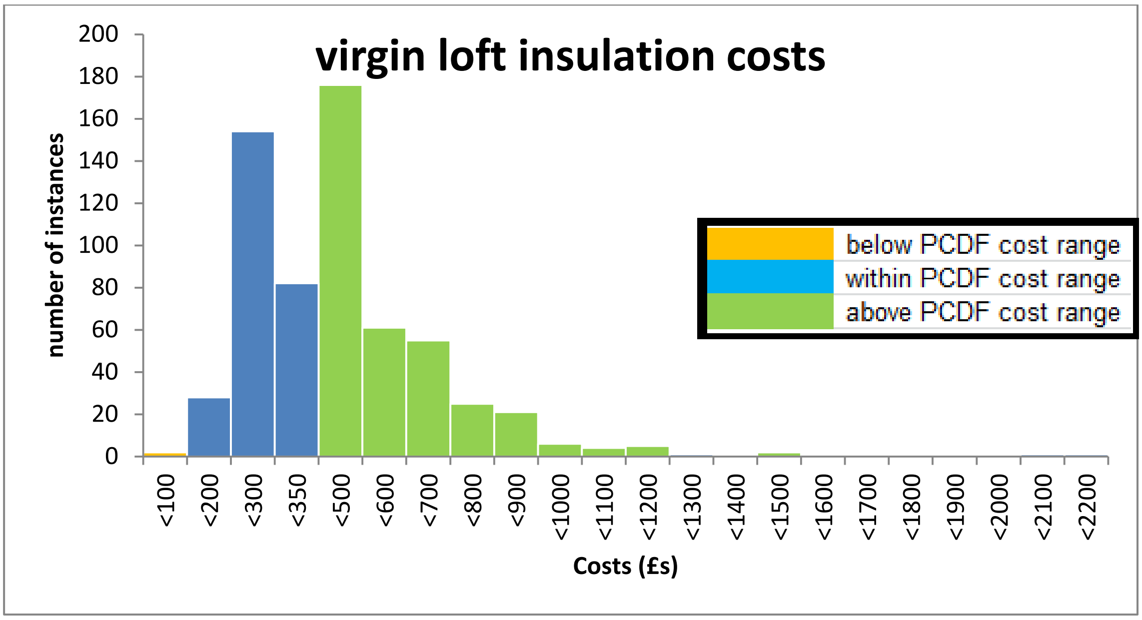


Figure A3.3: Range of virgin loft insulation costs calculated from 355 archetypes data



9.14 For the top-up loft insulation, the majority of costs fall within the PCDF range of £100 to £350, which is not the case with the virgin loft insulation costs, where the majority fall outside the PCDF range, with most being higher than the PCDF range. This situation is repeated with the mean and median costs for the two measures, with the top up mean and median costs falling within the PCDF range and the virgin loft costs being higher. Compared to the costs used in the modelling, mean contractor costs were 12% lower for top-up insulation and 25% higher for virgin loft insulation.

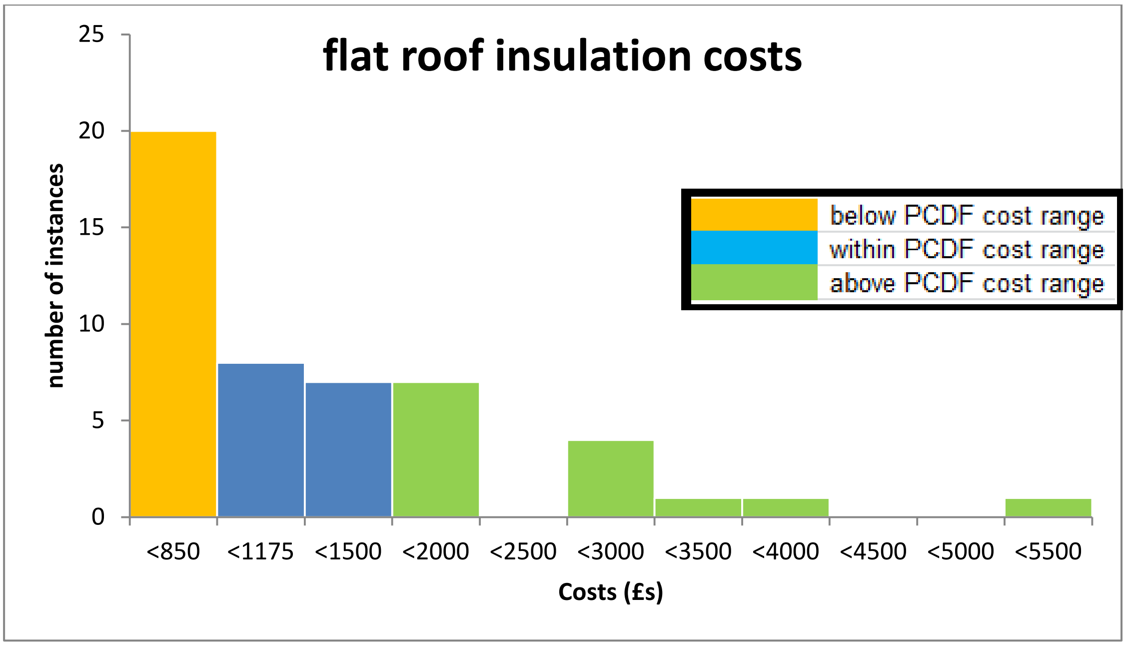
Flat Roof Insulation Costs

9.15 In Figure A3.4, the range of costs for flat roof loft insulation is presented. There are considerably fewer instances of flat roofs amongst the 355 archetypes than pitched roofs. For flat roof insulation the calculated contractor costs ranged between £200 and £5300 (see Table A3.4).

Table A3.4: Flat Roof Costs

	Flat roof insulation
Number of instances (n)	49
Number > £1500	14
Number <£850	20
% outside PCDF range	68%
Mean cost	£1,310
Median cost	£950
Maximum cost	£5,300
Minimum cost	£200
Cost used in modelling	£1,175
% difference between mean contractor and cost used in modelling	+12%

Figure A3.4: Range of flat roof insulation costs calculated from 355 archetypes data



9.16 For the flat roof insulation, the majority of costs fall outside the PCDF range of £850 to £1500, with the largest number coming in lower than the PCDF range.

This probably reflects that many of the instances of flat roofs within this data set were on small extensions rather than the main dwelling. The mean and median figures for flat roof insulation fall within the PCDF range. Compared to the costs used in the modelling, mean contractor costs were 12% higher.

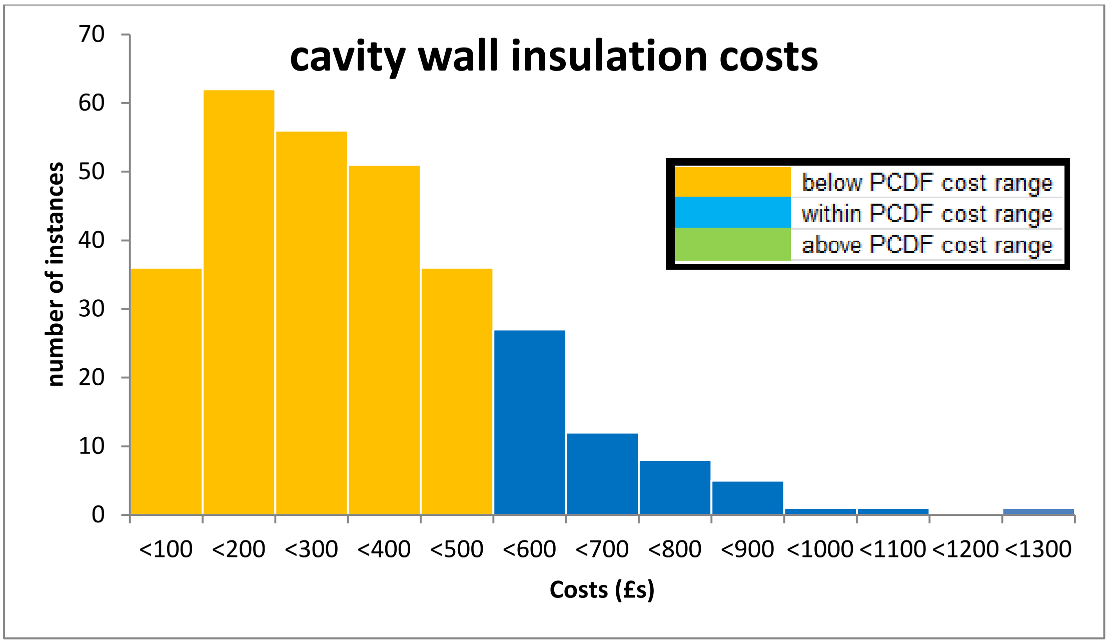
Cavity Wall Insulation Costs

9.17 In Figure A3.5, the range of costs for cavity wall insulation is presented, with the calculated contractor costs ranging between £47 and £1215 (see Table A3.5).

Table A3.5: Cavity Wall Insulation Costs

	Cavity wall insulation
Number of instances (n)	296
Number > £1500	0
Number <£500	241
% outside PCDF range	81%
Mean cost	£323
Median cost	£295
Maximum cost	£1,215
Minimum cost	£47
Cost used in modelling	£1,000
% difference between mean contractor and cost used in modelling	-68%

Figure A3.5: Range of cavity wall insulation costs calculated from 355 archetypes data



9.18 For the cavity wall insulation, the majority of costs fall outside the PCDF range of £500 to £1500. None of the calculated costs were greater that the PCDF higher limit, but 81% were lower than the PCDF lower limit. The mean and median figures for cavity wall insulation fell below the PCDF range. Compared to the costs used in the modelling, mean contractor costs were 68% lower.

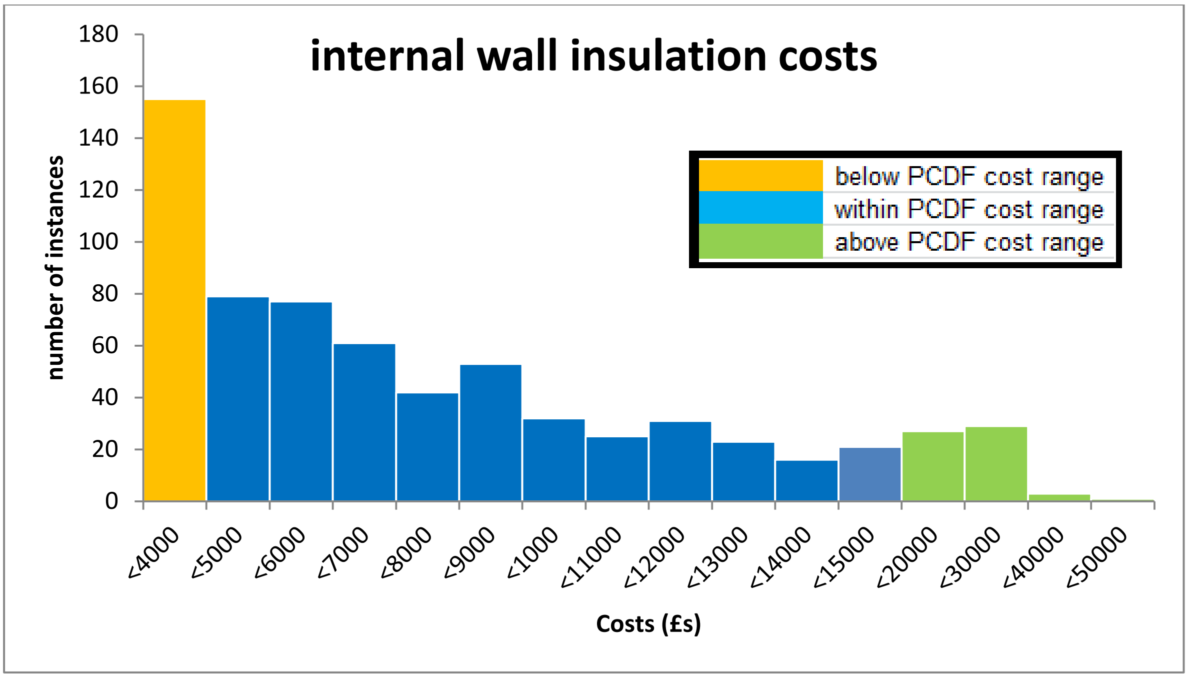
Internal Wall Insulation

9.19 In Figure A3.6, the range of costs for internal insulation is presented, with the calculated contractor costs ranging between £950 and £40,200 (see Table A3.6).

Table A3.6: Internal Wall Insulation Costs

	Internal wall insulation
Number of instances (n)	675
Number > £14,000	81
Number <£4,000	155
% outside PCDF range	35%
Mean cost	£7,977
Median cost	£6,370
Maximum cost	£40,200
Minimum cost	£950
Cost used in modelling	£9,000
% difference between mean contractor and cost used in modelling	-11%

Figure A3.6: Range of internal wall insulation costs calculated from 355 archetypes data



9.20 For the internal wall insulation, despite some very high costs, the majority of costs fall within the PCDF range of £4,000 to £14,000, as did both the mean and median figures for internal wall insulation. Compared to the costs used in the modelling, mean contractor costs were 68% lower.

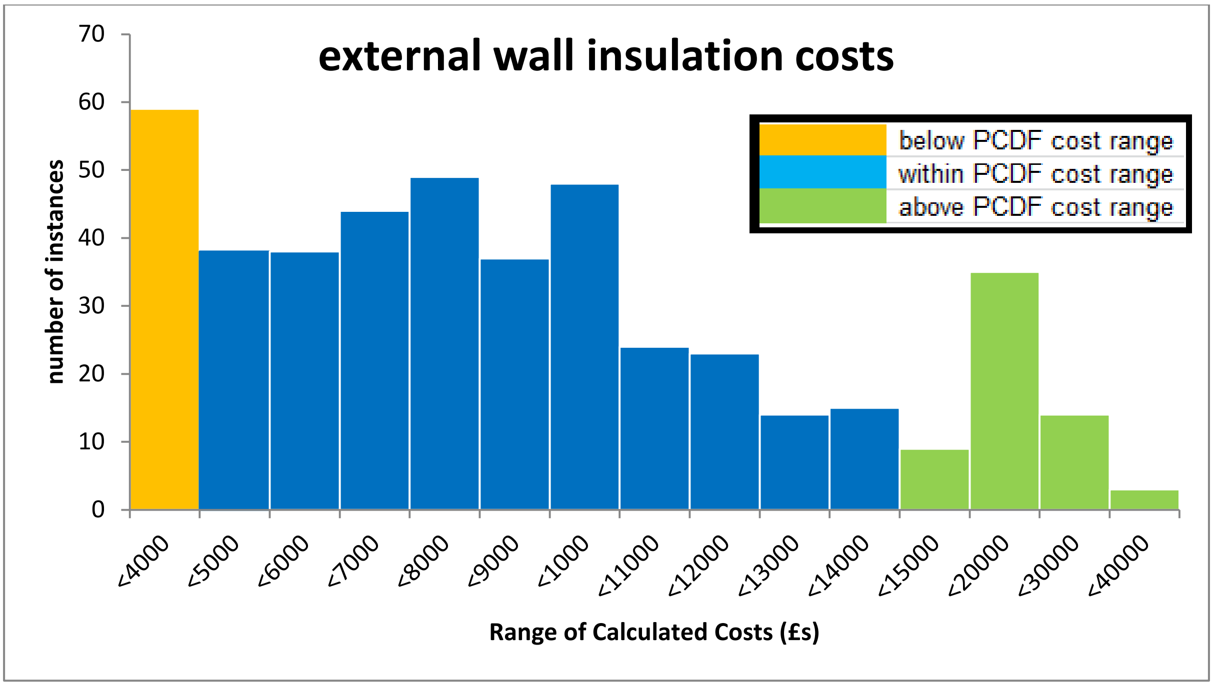
External Wall Insulation Costs

9.21 In Figure A3.7, the range of costs for external insulation is presented, with the calculated contractor costs ranging between £1520 and £33,500 (see Table A3.7).

Table A3.7: External Wall Insulation Costs

	External wall insulation
Number of instances (n)	450
Number > £14,000	61
Number <£4,000	59
% outside PCDF range	27%
Mean cost	£8,974
Median cost	£8,000
Maximum cost	£33,500
Minimum cost	£1,520
Cost used in modelling	£9000
% difference between mean contractor and cost used in modelling	0%

Figure A3.7: Range of external wall insulation costs calculated from 355 archetypes data



9.22 As with the internal wall insulation costs, the majority of the external wall insulation costs, despite some very high costs, fall within the PCDF range of £4,000 to £14,000 (73%), as did both the mean and median figures for internal wall insulation. Compared to the costs used in the modelling, mean contractor costs were identical.

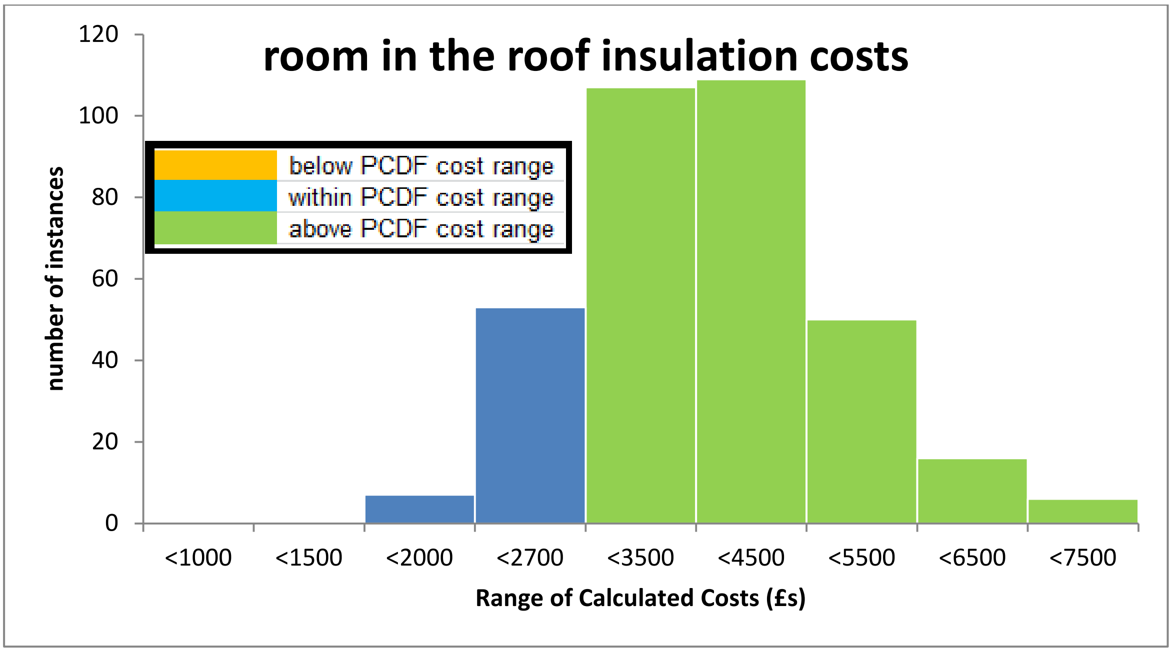
Room in the Roof Insulation

9.23 In Figure A3.8, the range of costs for room in the roof insulation is presented, with the calculated contractor costs ranging between £1556 and £7159 (see Table A3.8).

Table A3.8: Room In the Roof Insulation Costs

	Room in the Roof insulation
Number of instances (n)	348
Number > £14,000	288
Number <£4,000	0
% outside PCDF range	83%
Mean cost	£3697
Median cost	£3552
Maximum cost	£7159
Minimum cost	£1556
Cost used in modelling	£2,100
% difference between mean contractor and cost used in modelling	+76%

Figure A3.8: Range of room in the roof insulation costs calculated from 355 archetypes data



9.24 For the room in the roof insulation, the majority of costs fall outside the PCDF range of £1500 to £2700. None of the calculated costs were lower than the PCDF lower limit of £1500, but 83% were higher than the PCDF higher limit. The mean and median figures for room in the roof insulation were both higher than the PCDF range. Compared to the costs used in the modelling, mean contractor costs were 76% higher.

Floor Insulation Costs

9.25 In Figures A3.9 and A3.10, the range of costs for suspended timber floor insulation (i.e. where there is some void space beneath the floor that can be insulated) and solid floor insulation (i.e. the insulation has to be laid on top of the existing floor) are presented. For the suspended timber floor insulation the calculated contractor costs ranged between £96 and £5680, while the solid floor insulation costs ranged between £104 and £4200 (see Table A3.9).

Table A3.9: Floor Insulation Costs

	Suspended timber floor insulation	Solid floor insulation
Number of instances (n)	226	166
Number > £1200	113	100
Number <£800	63	54
% outside PCDF range	79%	93%
Mean cost	£1221	£1405
Median cost	£1096	£1407
Maximum cost	£5680	£4200
Minimum cost	£96	£104
Cost used in modelling	£1,000	£1,000
% difference between mean contractor and cost used in modelling	+22%	+41%

Figure A3.9: Range of suspended timber floor insulation costs calculated from 355 archetypes data

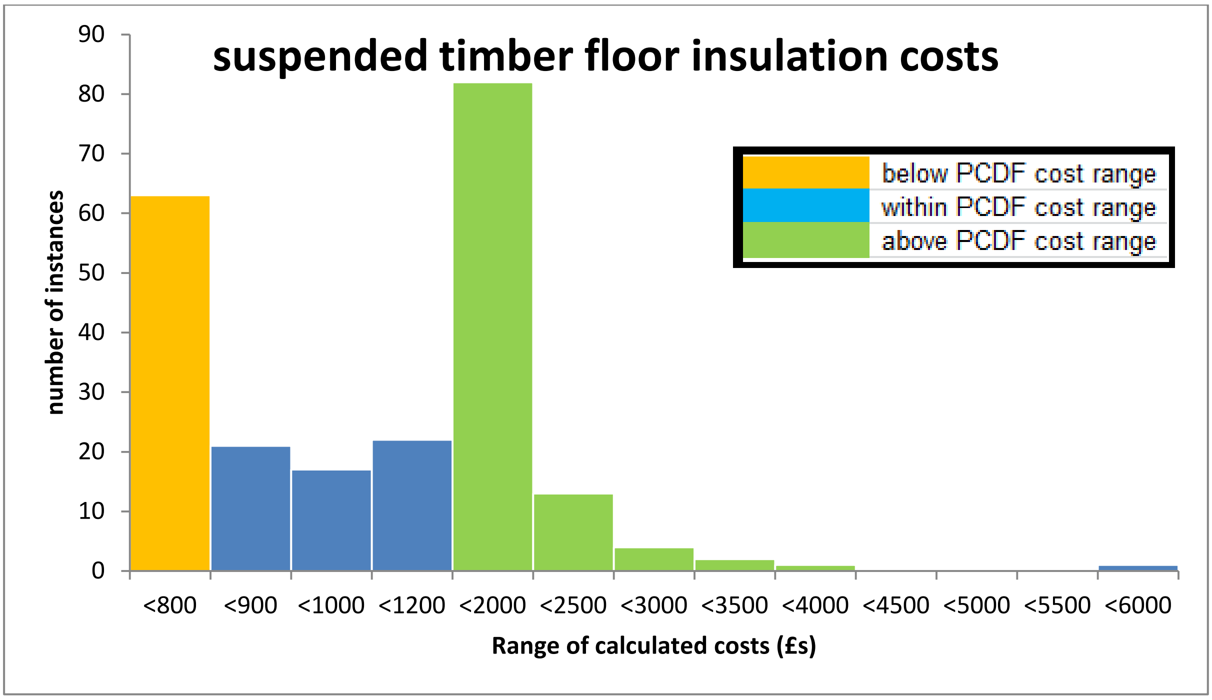
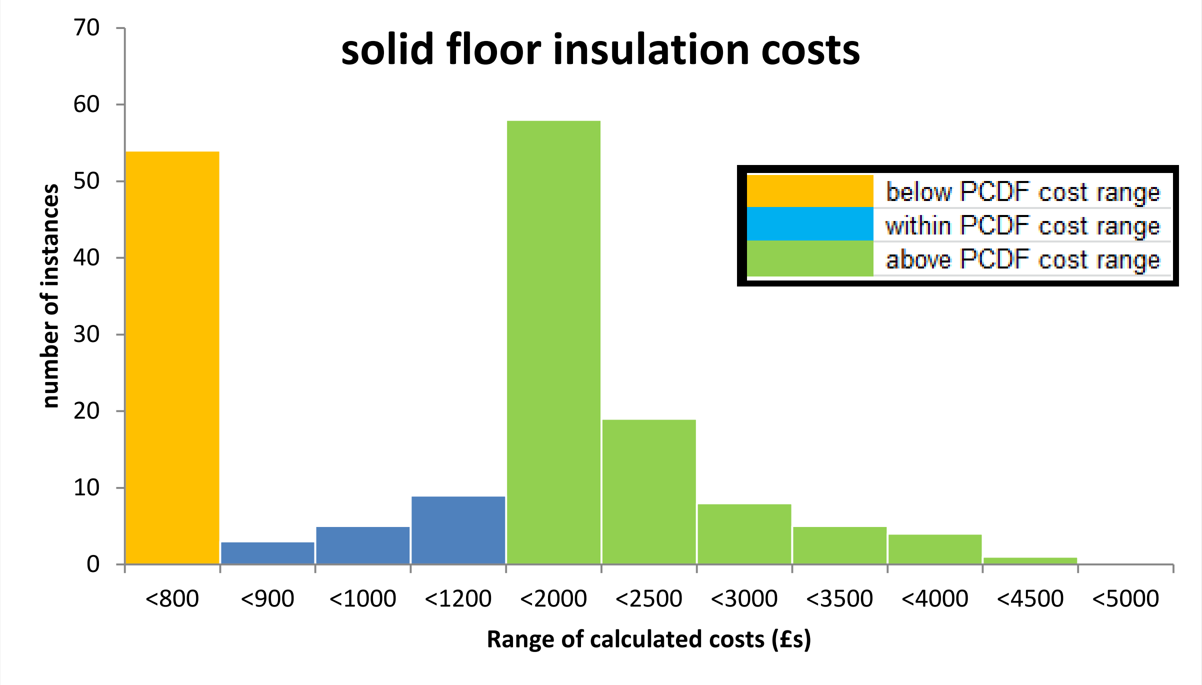


Figure A3.10: Range of suspended solid floor insulation costs calculated from 355 archetypes data



9.26 For the floor insulation costs, the majority of costs for both suspended timber floor and solid floor insulation fall outside the PCDF range of £800 to £1200, but the mean and median costs are either within the PCDF range or just above it. Solid floor insulation is slightly more expensive than the suspended timber floor insulation. Compared to the costs used in the modelling, mean contractor costs were 22% higher for suspended timber and 41% higher for solid floor insulation.

Comment on the Calculated Costs Exercise

9.27 What emerges from this exercise is the wide variability in prices when they are costed on a square metre basis. Further, there is no consistent bias one way or the other when these calculated costs are compared are against the PCDF range of cost.

9.28 The calculated contractor costs for cavity wall insulation were generally much less than the PCDF range. By contrast; the calculated costs for floor insulation, room in the roof insulation and virgin loft insulation were generally higher than the PCDF range. Solid wall insulation, external wall insulation and top up loft insulation were generally within the PCDF range. However, even when the majority of prices were outside the PCDF price range for a measure, the mean and median values were still generally within the PCDF range or close to it.

9.29 For other measures where costs are directly comparable, contractor costs were substantially lower for (i) fitting cylinder thermostat, (ii) upgrading combi boiler- mains gas, (iii) solar water heating.

Comments on Other Cost Comparisons

9.30 There was also a mixed picture in comparisons of PCDF mean costs with those used in the Parity Project, where a direct comparison could be made. In particular, the Parity Project costs were substantially higher for hot water cylinder jacket insulation, low energy lights and insulated doors. They were considerably lower for cavity wall insulation, upgrading mains gas combi boilers, converting to condensing gas boilers and radiators, solar water heating and ground source heat pumps with radiators. Costs were similar for loft insulation and fitting a cylinder thermostat.

9.31 Direct comparisons with most of the SPONS costs provided could not be made with mean PCDF costs, due to the use of different cost units.

The background and basis of PCDF costs

9.32 In 2011, with the extension of the range of measures when RdSAP 2009 v9.91 was launched, the EST provided Communities and Local Government (CLG – a department of the UK Government) with updated improvement costs for use in the Energy Performance Certificates (EPCs). The array of cost ranges for the various energy efficiency measures was intended to provide a broad range of indicative costs according to the available data at that time.

9.33 For example, the solid wall insulation cost range of between £4000 and £14,000 was derived from research the EST commissioned on the Solid Wall Insulation Supply Chain conducted by Purple Market Research Group. The range represented the lower cost estimation for internal solid wall insulation and the upper cost for the cost of external solid wall insulation. When the EST reviewed the data they found it corroborated the estimates from DECC Impact Assessments (IA) from DECC’s Climate and Energy Science Advisory Team (CESA), therefore it was agreed to use the CESA range.

9.34 All the published figures supplied were intended as indicative ranges to encompass the majority of household types and circumstances, to give an indicative estimation of the range of costs householders could expect. With a lot of energy efficiency measures, it was recognised that costs are highly variable and influenced by property circumstances such as construction type, installation methods, location, thickness, material etc.

9.35 BRE staff responsible for overseeing SAP and RdSAP confirmed the price ranges in the PCDF come from the EST.

9.36 While the fuel prices quoted on the EPC change on a 6-monthly basis, the improvement costs seem to be still those from the original implementation of RdSAP in 2012. It would appear that the EST themselves do not use the PCDF improvement costs. On the EST website, they note they “have updated our costs and the new costs ranges can be found on our website at: http://www.energysavingtrust.org.uk/Insulation"

9.37 On this website there are different costs quoted, sometimes for specific dwelling types, sometimes ballpark ranges, and sometimes not at all, which are summarised in Table A3.10. From this table, the quoted loft insulation costs are generally within the PCDF range, though the virgin loft insulation cost for the detached dwelling exceeds the PCDF range. The cavity wall insulation costs are considerably lower than the PCDF range, and in keeping with the calculated cost for cavity wall insulation calculated using the contractor data in para 9.17-9.18 above. The quoted range of internal and external wall insulation costs are greater than those quoted in the PCDF, as are the solid floor insulation costs. The suspended timber floor costs are lower than the PCDF range.

Table A3.10: EST Web-site Insulation Costs

	Detached house	**Semi-detached**	**Mid terrace**	**Detached bungalow**	**Flat**
Loft insulation 0mm to 270mm	£395	£300	£285	£265	nq
Loft insulation top up 100mm to 270mm	£265	£220	£215	£205	nq
Cavity wall insulation	£720	£475	£370	£430	£330
External wall insulation	£9,000 to £26,000				
Internal wall insulation	£4,000 to £16,000				
Solid floor insulation	£900 to £2400				
Suspended timber floor insulation	£300 to £700				
Draughtproofing	£100 DIY, "double that if professionally installed"				
Glazing	No costs quoted				

9.38 The EST stated that, "All our costs by different house types published on our website are based on BRE Standard Dwelling Dimension, information on the characteristics of the house types can be found on our assumption pages: http://www.energysavingtrust.org.uk/Energy-Saving-Trust/Our-calculations"

9.39 This summary of assumptions is produced in Table A3.11.

Table A3.11: EST Assumptions Used in Calculating Insulation Costs

	Semi-detached house	Detached house	Detached bungalow	Mid-terrace house	Mid-floor flat
Number of bedrooms	3	4	2	3	2
Floor area (m2)	89	149	67	79	60
Window area (m2)	17	24	9	13	7
Door area (m2)	3.7	3.7	3.7	3.7	1.85
Exposed wall U-value (W / m2 K)	1.1	1.1	1.1	1.1	1.1
Roof U-value (W / m2 K)	0.32	0.32	0.32	0.32	0

9.40 An BRE document entitled 'Standard Dwellings for Energy Modelling' was originally produced in 1999, and updated in 2012, which includes a number of different dwelling types, along with their respective floor plans, elevations and dimensions. From the EST dwelling data above, the semi-detached house above appears to be consistent with the large semi-detached house (1945-64) in the BRE document; the detached dwelling above consistent with the large detached house (1965-80) in the BRE document; the detached bungalow above consistent with the detached bungalow (post 1990) in the BRE document; the mid terrace house above consistent with the modern mid-terrace house (1990-2001) in the BRE document; and the mid floor flat above consistent with the 2-bedroom flat (1945-1964) in the BRE document.

Table A3.12: BRE Standard Dwelling Dimensional Data

	Detached house	Semi-detached house	Mid terrace house	Detached bungalow	Flat
Loft insulation area	74.25m^2	44.37 m^2	39.44 m^2	67.32 m^2	60.94 m^2 [83]
Gross external wall area	199.7 m^2	102.5 m^2	92 m^2	80.16 m^2	37.68 m^2 [84]
Heat Loss floor area	74.2 m^2	44.37 m^2	39.44 m^2	67.32 m^2	60.94 m^2 [85]

9.41 Combining this BRE dimensional data and the costs from the EST website allows a basic cost per m^2 for each insulation measure to be calculated (see Table A3.13).

Table A3.13: Derived m^2 Insulation costs

	Detached house	Semi-detached	Mid terrace	Detached bungalow	Flat
Loft insulation 0mm to 270mm	£5.32	£6.76	£7.23	£3.94	nq
Loft insulation top up 100mm	£3.57	£4.95	£5.45	£3.05	nq

[83] Assuming the mid floor flat has a top floor version of the same dimensions
[84] Not including any wall backing on to a corridor or circulation area
[85] Assuming the mid floor flat has a ground floor version of the same dimensions

to 270mm					
Cavity wall insulation	£3.61	£4.63	£4.02	£5.36	£8.76
Solid floor insulation	£12.12 – 32.32	£20.28 - £54.09	£22.82 - £60.85	£13.37 - £35.65	nq
Suspended timber floor insulation	£4.04 - £9.43	£6.76 - £15.78	£7.61 - £17.75	£4.46 - £10.40	nq
External wall insulation	£45.07 - £130.19	£87.80 - £253.66	£97.83 - £282.61	£112.28 - £324.35	£238.85 - £690.02
Internal wall insulation	£20.03 – £130.19	£39.02 - £156.10	£43.48 - £173.91	£49.90 - £199.60	£106.16 - £424.63

9.42 What emerges from the EST data is that again there are a wide range of costs, and no consistency, across the different dwelling types for the different insulation measures.

Overall comment

9.43 As already noted above, the PCDF improvement cost figures were intended to provide an indicative range of cost for different energy efficiency measures within the energy advice report of the EPC, covering the broad majority of household types and circumstances, so as to provide the householder with an estimation of the range of costs they could expect. It was recognised that the costs are highly variable for a wide range of reasons. Just how variable the improvement costs can be was only further emphasised by the calculated cost exercise carried out using the archetype dimensional data and the unit prices obtained from three Scottish contractors. Yet, despite the high degree of variability within the calculated costs of the different insulation measures examined, many of the mean and median costs fell within the PCDF range of costs for the respective measure. Comparisons of mean contractor costs with those used in the modelling did however show large differences, both higher and lower, for some of the insulation measures.

9.44 The REEPS RAG took the decision to use the Product Characteristics Database File (PCDF) costs for improvement measures, in the absence of a robust, comprehensive, nationally recognised, evidence based, alternative. RAG was not willing to base the research modelling on prices quoted by a small number of contractors. RAG was also mindful of ensuring research results were consistent with EPC reports, which are based on PCDF costs.

9.45 In addition, RAG took the decision to use mean PCDF costs, as corresponding unit costs were not available. It was recognised by RAG that this will lead to some over/under estimation of costs for individual archetypes, depending on their size and other characteristics. However, the use of mean costs would result in the best central estimates for the aggregated results.

10 APPENDIX 4: DETAILS OF LOW PREVALENCE ARCHETYPES

10.1 The table below gives details of the low prevalence groupings that each account for between 0.5% and 0.1% of the target stock, as discussed in Chapter 3.

Table A4.1: Summary of the low prevalence combinations.

Initial Combination	Total sub-groups	Dwellings	%age of target stock	N	% in E[86]	% in F	% in G
Pre-1919-Semi/End Terr'-Sandstone-LPG boiler	3	1950	0.5%	8	14%	74%	12%
1919-1964-Semi/End Terr'-Granite-Mains Gas boiler	1	1950	0.5%	7	100%		
Pre-1919-4-in-a-block-Sandstone-Mains Gas boiler	2	1900	0.5%	8	86%	14%	
1919-1964-Tenement-Cavity Brick-Electric peak room heater	2	1900	0.5%	5	58%	42%	
1965-1975-Tenement-Cavity Brick-Off Peak Electric storage heating	1	1900	0.5%	7	100%		
1984-1991-Detached-Timber-Off Peak Electric storage heating	1	1750	0.4%	10	100%		
1919-1964-Semi/End Terr'-Cavity Brick-Solid fuel boiler	2	1750	0.4%	9	51%	49%	
1965-1975-Detached-Timber-Off Peak Electric storage heating	2	1700	0.4%	12	51%	49%	
1919-1964-Semi/End Terr'-Sandstone-Mains Gas boiler	1	1700	0.4%	7	100%		
Pre-1919-Mid-ter/Terr with passage/Enc' end-Sandstone-Mains Gas boiler	1	1700	0.4%	6	100%		
1965-1975-Tenement-Cavity Brick-Electric peak room heater	3	1600	0.4%	5	12%	63%	25%
1976-1983-Detached-Timber-Off Peak Electric storage heating	1	1600	0.4%	13	100%		
1984-1991-Tenement-Cavity Brick-Off Peak Electric storage heating	2	1600	0.4%	5	72%	28%	
Post 1991-Detached-Timber-Off Peak Electric storage heating	2	1550	0.4%	14	97%	3%	
1984-1991-Detached-Cavity Brick-Off Peak Electric storage heating	1	1550	0.4%	11	100%		
Pre-1919-Semi/End Terr'-Sandstone-Solid fuel boiler	3	1550	0.4%	5	67%	17%	15%
1965-1975-Semi/End Terr'-System-Off Peak Electric storage heating	2	1500	0.4%	6	70%	30%	
1919-1964-Mid-ter/Terr with passage/Enc' end-Cavity Brick-Mains Gas boiler	1	1400	0.3%	5	100%		
Pre-1919-Mid-ter/Terr with passage/Enc' end-Granite-Off Peak Electric storage heating	2	1350	0.3%	5	62%	38%	
1976-1983-Semi/End Terr'-Cavity Brick-Off Peak Electric storage heating	1	1350	0.3%	6	100%		
1984-1991-Detached-Timber-LPG boiler	3	1350	0.3%	7	41%	54%	5%
Pre-1919-Detached-Sandstone-Solid fuel boiler	3	1300	0.3%	9	36%	41%	23%

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1919-1964-Semi/End Terr'-System-Off Peak Electric storage heating	2	1300	0.3%	5	72%	28%	
Post 1991-Detached-Cavity Brick-Oil boiler	1	1250	0.3%	6	100%		
1919-1964-Detached-Cavity Brick-LPG boiler	2	1200	0.3%	5		62%	38%
1976-1983-Semi/End Terr'-Cavity Brick-Mains Gas boiler	1	1200	0.3%	3	100%		
1976-1983-Semi/End Terr'-Timber-Off Peak Electric storage heating	2	1150	0.3%	6	97%	3%	
1976-1983-Detached-Cavity Brick-Mains Gas boiler	1	1150	0.3%	5	100%		
1919-1964-Detached-Sandstone-Oil boiler	3	1150	0.3%	19	80%	17%	3%
Post 1991-Detached-Timber-LPG boiler	2	1150	0.3%	7	83%		17%
Pre-1919-Flat from converted house-Sandstone-Electric peak room heater	2	1100	0.3%	5	45%		55%
1965-1975-Detached-Timber-Oil boiler	2	1100	0.3%	8	97%	3%	
Pre-1919-Flat from converted house-Granite-Mains Gas boiler	1	1100	0.3%	3	100%		
Pre-1919-Detached-Granite-LPG boiler	2	1100	0.3%	4		25%	75%
1965-1975-Detached-Cavity Brick-Oil/Gas/Electric warm air	2	1100	0.3%	4	68%	32%	
1919-1964-Detached-System-Mains Gas boiler	1	1050	0.3%	6	100%		
1976-1983-Tenement-Cavity Brick-Off Peak Electric storage heating	2	1050	0.3%	3	20%	80%	
1919-1964-Semi/End Terr'-Cavity Brick-Means gas room heater	2	1050	0.3%	3	66%	34%	
1919-1964-Semi/End Terr'-Timber-Off Peak Electric storage heating	2	1050	0.3%	7	76%	24%	
1965-1975-Detached-Cavity Brick-Electric peak/off-peak boiler	2	1050	0.3%	3		59%	41%
Pre-1919-Detached-Sandstone-Solid fuel/wood room heater	3	1000	0.3%	6	4%	93%	4%
1965-1975-Mid-ter/Terr with passage/Enc' end-Cavity Brick-Off Peak Electric storage heat	1	950	0.2%	6	100%		
1984-1991-Detached-Cavity Brick-Mains Gas boiler	1	950	0.2%	4	100%		
1984-1991-Detached-Cavity Brick-Oil boiler	1	950	0.2%	5	100%		
Pre-1919-Detached-Granite-Solid fuel/wood room heater	2	950	0.2%	3	16%		84%
Pre-1919-Detached-Solid brick/Cob-Oil boiler	2	950	0.2%	4	4%	96%	
Pre-1919-Detached-Sandstone-Wood boiler	2	950	0.2%	4	96%	4%	
1965-1975-Detached-System-Oil boiler	1	900	0.2%	2	100%		
1965-1975-Semi/End Terr'-Cavity Brick-Oil boiler	1	900	0.2%	4	100%		
Pre-1919-Mid-ter/Terr with passage/Enc' end-Sandstone-Solid fuel boiler	1	900	0.2%	4	100%		
1965-1975-Detached-System-Mains Gas boiler	1	850	0.2%	3	100%		
Post 1991-Tenement-Cavity Brick-Off Peak Electric storage heating	1	850	0.2%	2	100%		
1965-1975-Mid-ter/Terr with passage/Enc' end-Cavity Brick-Electric peak/off-peak boiler	1	850	0.2%	2	100%		

1976-1983-Detached-Cavity Brick-Off Peak Electric storage heating	1	850	0.2%	8	100%		
Pre-1919-Semi/End Terr'-Granite-Solid fuel boiler	2	850	0.2%	3	34%	66%	
1919-1964-Semi/End Terr'-Cavity Brick-LPG boiler	3	850	0.2%	3	28%	27%	45%
1919-1964-Tenement-Solid brick/Cob-Mains Gas boiler	2	800	0.2%	2	53%	47%	
Pre-1919-Detached-Granite-Electric peak room heater	2	800	0.2%	2		49%	51%
1919-1964-Detached-Sandstone-Mains Gas boiler	1	800	0.2%	2	100%		
1919-1964-Detached-System-Solid fuel boiler	3	800	0.2%	3	46%	31%	23%
1984-1991-Detached-Timber-Electric peak/off-peak boiler	2	800	0.2%	2	47%	53%	
1919-1964-Detached-System-Oil boiler	3	800	0.2%	15	69%	26%	5%
1919-1964-Detached-Granite-Oil boiler	2	800	0.2%	2	45%	55%	
Pre-1919-Detached-Granite-Solid fuel boiler	1	750	0.2%	2		100%	
1919-1964-Mid-ter/Terr with passage/Enc' end-Sandstone-Mains Gas boiler	1	700	0.2%	2	100%		
1984-1991-Detached-Cavity Brick-LPG boiler	2	700	0.2%	2	42%	58%	
1919-1964-Semi/End Terr'-Timber-Oil boiler	1	700	0.2%	3	100%		
Pre-1919-4-in-a-block-Solid brick/Cob-Mains Gas boiler	1	700	0.2%	3	100%		
Pre-1919-4-in-a-block-Sandstone-Off Peak Electric storage heating	2	700	0.2%	4	57%	43%	
Pre-1919-Mid-ter/Terr with passage/Enc' end-Sandstone-Oil boiler	1	700	0.2%	3	100%		
1965-1975-Semi/End Terr'-Cavity Brick-Electric peak/off-peak boiler	2	700	0.2%	2	48%	52%	
Pre-1919-Mid-ter/Terr with passage/Enc' end-Sandstone-Off Peak Electric storage heating	1	700	0.2%	4	100%		
Pre-1919-Tenement-Granite-Electric peak room heater	2	650	0.2%	2	50%		50%
Pre-1919-Tenement-Sandstone-Solid fuel/wood room heater	1	650	0.2%	2		100%	
1965-1975-Mid-ter/Terr with passage/Enc' end-Cavity Brick-Electric peak room heater	2	650	0.2%	2	60%	40%	
1919-1964-Tenement-System-Mains Gas boiler	1	650	0.2%	2	100%		
1919-1964-Detached-System-Off Peak Electric storage heating	2	650	0.2%	8		95%	5%
Pre-1919-4-in-a-block-Granite-Mains Gas boiler	2	600	0.2%	2	100%		
1919-1964-4-in-a-block-Cavity Brick-Off Peak Electric storage heating	2	600	0.2%	3	59%	41%	
Post 1991-Detached-Sandstone-Oil boiler	2	600	0.2%	2	66%	34%	

1919-1964-Semi/End Terr'-Cavity Brick-Electric peak/off-peak boiler	2	600	0.2%	3		19%	81%
Pre-1919-Mid-ter/Terr with passage/Enc' end-Granite-Mains Gas boiler	1	600	0.2%	2	100%		
1965-1975-Detached-System-LPG boiler	2	600	0.2%	2		32%	68%
Post 1991-Tenement-Cavity Brick-Electric peak room heater	1	600	0.1%	2	100%		
Post 1991-Detached-Timber-Oil boiler	1	600	0.1%	3	100%		
Pre-1919-Semi/End Terr'-Solid brick/Cob-Oil boiler	1	550	0.1%	3	100%		
Post 1991-Detached-Timber-Mains Gas boiler	1	550	0.1%	2	100%		
Post 1991-Semi/End Terr'-Granite-LPG boiler	1	550	0.1%	1	100%		
Post 1991-Detached-Granite-Oil boiler	1	550	0.1%	3	100%		
1965-1975-Mid-ter/Terr with passage/Enc' end-System-Off Peak Electric storage heating	1	550	0.1%	2	100%		
Pre-1919-Tenement-Solid brick/Cob-Mains Gas boiler	1	550	0.1%	2	100%		
Pre-1919-Semi/End Terr'-Sandstone-Electric peak room heater	2	550	0.1%	2		51%	49%
Pre-1919-Flat from converted house-Sandstone-Oil boiler	2	550	0.1%	3	93%	7%	
1976-1983-Mid-ter/Terr with passage/Enc' end-Timber-Electric peak room heater	1	550	0.1%	1	100%		
1965-1975-Semi/End Terr'-Timber-Mains Gas boiler	1	550	0.1%	2	100%		
Pre-1919-Flat from converted house-Solid brick/Cob-Mains Gas boiler	1	500	0.1%	2	100%		
1919-1964-4-in-a-block-System-Mains Gas boiler	1	500	0.1%	2	100%		
Post 1991-Flat from converted house--Sandstone-Mains Gas boiler	1	500	0.1%	2	100%		
Pre-1919-Detached--Granite-Wood boiler	1	500	0.1%	3		100%	
1919-1964-Mid-ter/Terr with passage/Enc' end-Cavity Brick-Electric peak/off-peak boiler	1	500	0.1%	2		100%	
1965-1975-Detached-Timber-LPG boiler	1	500	0.1%	2		100%	
Pre-1919-Semi/End Terr'-Sandstone-Wood boiler	1	500	0.1%	2	100%		
1984-1991-Semi/End Terr'-Timber-Off Peak Electric storage heating	1	500	0.1%	3	100%		
1976-1983-Detached-Cavity Brick-LPG boiler	1	500	0.1%	3		100%	
1984-1991-Detached-Timber-Oil boiler	1	500	0.1%	2	100%		
1919-1964-Detached-Solid brick/Cob-Oil boiler	2	500	0.1%	3	8%	92%	
Pre-1919-Tenement-Solid brick/Cob-Means gas room heater	1	500	0.1%	1		100%	
Post 1991-Semi/End Terr'-Sandstone-LPG boiler	1	500	0.1%	2	100%		
Pre-1919-Semi/End Terr'-Sandstone-Electric peak/off-peak boiler	1	500	0.1%	2	100%		
1965-1975-Semi/End Terr'-Timber-Oil/Gas/Electric warm air	1	500	0.1%	2	100%		

1919-1964-Detached-Granite-Off Peak Electric storage heating	1	450	0.1%	1			100%
1965-1975-Tenement-System-Off Peak Electric storage heating	1	450	0.1%	1	100%		
Post 1991-Tenement-Granite-Off Peak Electric storage heating	1	450	0.1%	1	100%		
1919-1964-Tenement-Granite-Electric peak room heater	1	450	0.1%	1	100%		
Pre-1919-Flat from converted house-Sandstone-Off Peak Electric storage heating	2	450	0.1%	2	60%	40%	
Pre-1919-Semi/End Terr'--Cavity Brick-Electric peak room heater	1	450	0.1%	1			100%
Pre-1919-Tenement--Sandstone-Community Heating	1	450	0.1%	1	100%		
1919-1964-Semi/End Terr'--Granite-Oil boiler	1	400	0.1%	2	100%		
1965-1975-Detached--Granite-Oil boiler	1	400	0.1%	1	100%		
1965-1975-Tenement--Timber-Off Peak Electric storage heating	1	400	0.1%	1	100%		
1976-1983-Detached--Timber-Mains Gas boiler	1	400	0.1%	1	100%		
Post 1991-Detached-Cavity Brick-Mains Gas boiler	1	400	0.1%	1	100%		
Post 1991-Tenement-Cavity Brick-LPG boiler	1	400	0.1%	1	100%		
Post 1991-Tower/Slab-Sandstone-Electric peak/off-peak boiler	1	400	0.1%	1		100%	
Post 1991-Tower/Slab-System-Off Peak Electric storage heating	1	400	0.1%	1	100%		

11 APPENDIX 5: DETAILS OF HOW THE VERY LOW PREVALENCE GROUPS WERE COLLAPSED INTO MODELLED ARCHETYPES

Table A5.1: Summary of the very low prevalence combinations and the archetypes they were collapsed into.

Initial combination	Collapsed into	Stage	%age of target stock covered by initial combination
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Solid brick/Cob-Mains Gas boiler	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler-E	1	0.10%
1919-1964-Detached-Sandstone-Solid fuel boiler	Pre-1919-Detached-Sandstone-Solid fuel boiler-E	1	0.02%
Pre-1919-Semi/End Terraced-Sandstone-Solid fuel/wood room heater	Pre-1919-Detached-Sandstone-Solid fuel/wood room heater-G-Subgroup 2	1	0.01%
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Solid fuel/wood room heater	Pre-1919-Detached-Sandstone-Solid fuel/wood room heater-G-Subgroup 1	1	0.09%
1919-1964-Detached-Sandstone-Wood boiler	Pre-1919-Detached-Sandstone-Wood boiler-F	1	0.02%
1919-1964-Detached-Sandstone-Off Peak Electric storage heating	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating-F-Subgroup 1	1	0.05%
1965-1975-Detached-Sandstone-Off Peak Electric storage heating	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating-F-Subgroup 1	1	0.01%
1919-1964-Semi/End Terraced-Granite-LPG boiler	Pre-1919-Detached-Granite-LPG boiler-F	1	0.03%
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Solid fuel/wood room heater	Pre-1919-Detached-Granite-Solid fuel/wood room heater-F	1	0.09%
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Electric peak room heater	Pre-1919-Detached-Granite-Electric peak room heater-G	1	0.09%
1919-1964-Semi/End Terraced-Granite-Electric peak room heater	Pre-1919-Detached-Granite-Electric peak room heater-G	1	0.06%
1919-1964-Semi/End Terraced-Solid brick/Cob-Oil boiler	Pre-1919-Semi/End Terraced-Solid brick/Cob-Oil boiler-G	1	0.09%
1919-1964-Detached-Sandstone-LPG boiler	Pre-1919-Semi/End Terraced-Sandstone-LPG boiler-G	1	0.04%
Pre-1919-Detached-Sandstone-Electric peak room heater	Pre-1919-Semi/End Terraced-Sandstone-Electric peak room heater-G	1	0.07%
1965-1975-Detached-Sandstone-Electric peak room heater	Pre-1919-Semi/End Terraced-Sandstone-Electric peak room heater-G	1	0.01%
1919-1964-Semi/End Terraced-Sandstone-Electric peak room heater	Pre-1919-Semi/End Terraced-Sandstone-Electric peak room heater-F	1	0.06%
1919-1964-Semi/End Terraced-Sandstone-Off Peak Electric storage heating	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating-F-Subgroup 2	1	0.10%
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Solid fuel boiler	Pre-1919-Semi/End Terraced-Granite-Solid fuel boiler-F-Subgroup 1	1	0.01%

1919-1964-Semi/End Terraced-Granite-Off Peak Electric storage heating	Pre-1919-Semi/End Terraced-Granite-Off Peak Electric storage heating-F-Subgroup 2	1	0.01%
1965-1975-Detached-Cavity Brick-Electric peak room heater	Pre-1919-Semi/End Terraced-Cavity Brick-Electric peak room heater-G	1	0.06%
1919-1964-Tenement-Sandstone-Mains Gas boiler	Pre-1919-Tenement-Sandstone-Mains Gas boiler-Lower E-Smaller	1	0.10%
Pre-1919-Flat from converted house-Granite-Off Peak Electric storage heating	Pre-1919-Tenement-Granite-Off Peak Electric storage heating-E-Subgroup 1	1	0.03%
Pre-1919-Tenement-Granite-Mains Gas boiler	Pre-1919-Flat from converted house-Granite-Mains Gas boiler-E	1	0.04%
1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Solid brick/Cob-Oil boiler	1919-1964-Detached-Solid brick/Cob-Oil boiler-F	1	0.06%
1965-1975-Detached-Cavity Brick-LPG boiler	1919-1964-Detached-Cavity Brick-LPG boiler-G	1	0.09%
Pre-1919-Detached-Cavity Brick-Oil boiler	1919-1964-Detached-Cavity Brick-Oil boiler-F-Subgroup 3	1	0.01%
1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Oil boiler	1919-1964-Detached-Cavity Brick-Oil boiler-F-Subgroup 1	1	0.06%
Pre-1919-Detached-System-Oil boiler	1919-1964-Detached-System-Oil boiler-F	1	0.02%
1919-1964-Semi/End Terraced-System-Solid fuel boiler	1919-1964-Detached-System-Solid fuel boiler-F-Subgroup 2	1	0.01%
1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Solid brick/Cob-Mains Gas boiler	1919-1964-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler-E	1	0.01%
1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Means gas room heater	1919-1964-Semi/End Terraced-Cavity Brick-Means gas room heater-F-Subgroup 1	1	0.04%
1965-1975-Semi/End Terraced-Cavity Brick-Means gas room heater	1919-1964-Semi/End Terraced-Cavity Brick-Means gas room heater-F-Subgroup 2	1	0.09%
1984-1991-Semi/End Terraced-Cavity Brick-Means gas room heater	1919-1964-Semi/End Terraced-Cavity Brick-Means gas room heater-F-Subgroup 2	1	0.03%
Pre-1919-Detached-Cavity Brick-LPG boiler	1919-1964-Semi/End Terraced-Cavity Brick-LPG boiler-G-Subgroup 1	1	0.10%
1965-1975-Detached-Cavity Brick-Solid fuel boiler	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 1	1	0.06%
1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Solid fuel boiler	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 1	1	0.04%
1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Solid fuel boiler	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 2	1	0.09%
1965-1975-Semi/End Terraced-Cavity Brick-Solid fuel boiler	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 2	1	0.01%
1976-1983-Detached-Cavity Brick-Solid fuel boiler	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 2	1	0.01%
1984-1991-Detached-Cavity Brick-Solid fuel boiler	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 2	1	0.01%

1919-1964-Detached-Timber-Oil boiler	1919-1964-Semi/End Terraced-Timber-Oil boiler-E	1	0.03%
1919-1964-Detached-Timber-Off Peak Electric storage heating	1919-1964-Semi/End Terraced-Timber-Off Peak Electric storage heating-F	1	0.09%
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-System-Off Peak Electric storage heating	1919-1964-Semi/End Terraced-System-Off Peak Electric storage heating-E-Subgroup 2	1	0.05%
1919-1964-Detached-Cavity Brick-Electric peak/off-peak boiler	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak/off-peak boiler-F	1	0.09%
1919-1964-4-in-a-block-Cavity Brick-Electric peak room heater	1919-1964-Tenement-Cavity Brick-Electric peak room heater-E-Subgroup 2	1	0.04%
1965-1975-Tower/Slab-Cavity Brick-Mains Gas boiler	1919-1964-4-in-a-block-Cavity Brick-Mains Gas boiler-Upper E	1	0.09%
1919-1964-Flat from converted house-Cavity Brick-Off Peak Electric storage heating	1919-1964-4-in-a-block-Cavity Brick-Off Peak Electric storage heating-E	1	0.04%
1919-1964-Detached-Cavity Brick-Oil/Gas/Electric warm air	1965-1975-Detached-Cavity Brick-Oil/Gas/Electric warm air-E-Subgroup 2	1	0.01%
1919-1964-Semi/End Terraced-Cavity Brick-Oil/Gas/Electric warm air	1965-1975-Detached-Cavity Brick-Oil/Gas/Electric warm air-E-Subgroup 2	1	0.04%
1976-1983-Detached-Cavity Brick-Electric peak/off-peak boiler	1965-1975-Detached-Cavity Brick-Electric peak/off-peak boiler-G-Subgroup 2	1	0.05%
1976-1983-Detached-Timber-LPG boiler	1965-1975-Detached-Timber-LPG boiler-F	1	0.04%
1976-1983-Detached-Timber-Oil boiler	1965-1975-Detached-Timber-Oil boiler-E	1	0.06%
1965-1975-Semi/End Terraced-Timber-Off Peak Electric storage heating	1965-1975-Detached-Timber-Off Peak Electric storage heating-E	1	0.03%
1965-1975-Semi/End Terraced-System-Mains Gas boiler	1965-1975-Detached-System-Mains Gas boiler-E	1	0.09%
1919-1964-Detached-System-LPG boiler	1965-1975-Detached-System-LPG boiler-F-Subgroup 2	1	0.08%
1919-1964-Semi/End Terraced-System-Oil boiler	1965-1975-Detached-System-Oil boiler-E	1	0.05%
Pre-1919-Detached-System-Off Peak Electric storage heating	1965-1975-Semi/End Terraced-System-Off Peak Electric storage heating-E	1	0.02%
1976-1983-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak/off-peak boiler-F	1	0.04%
1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak room heater	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak room heater-F	1	0.09%
1976-1983-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak room heater	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak room heater-E	1	0.09%
1919-1964-Mid-terrace/Terrace with passage/Enclosed end-System-Off Peak Electric storage heating	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-System-Off Peak Electric storage heating-E	1	0.07%

1984-1991-Detached-System-Off Peak Electric storage heating	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-System-Off Peak Electric storage heating-E	1	0.01%
1919-1964-Tower/Slab-Cavity Brick-Electric peak room heater	1965-1975-Tenement-Cavity Brick-Electric peak room heater-F-Subgroup 2	1	0.10%
1976-1983-Tower/Slab-Cavity Brick-Electric peak room heater	1965-1975-Tenement-Cavity Brick-Electric peak room heater-E	1	0.05%
1984-1991-4-in-a-block-Cavity Brick-Electric peak room heater	1965-1975-Tenement-Cavity Brick-Electric peak room heater-E	1	0.07%
1919-1964-Tenement-System-Off Peak Electric storage heating	1965-1975-Tenement-System-Off Peak Electric storage heating-E	1	0.09%
1965-1975-Detached-Timber-Mains Gas boiler	1976-1983-Detached-Timber-Mains Gas boiler-E	1	0.07%
1965-1975-4-in-a-block-Cavity Brick-Off Peak Electric storage heating	1976-1983-Tenement-Cavity Brick-Off Peak Electric storage heating-E-Subgroup 2	1	0.01%
1984-1991-Semi/End Terraced-Cavity Brick-Mains Gas boiler	1984-1991-Detached-Cavity Brick-Mains Gas boiler-E	1	0.06%
Post 1991-Detached-Cavity Brick-LPG boiler	1984-1991-Detached-Cavity Brick-LPG boiler-F	1	0.05%
1984-1991-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating	1984-1991-Detached-Cavity Brick-Off Peak Electric storage heating-E	1	0.08%
Post 1991-Semi/End Terraced-Timber-Oil boiler	1984-1991-Detached-Timber-Oil boiler-E	1	0.06%
Post 1991-Detached-Timber-Electric peak/off-peak boiler	1984-1991-Detached-Timber-Electric peak/off-peak boiler-E-Subgroup 2	1	0.03%
1976-1983-4-in-a-block-Cavity Brick-Off Peak Electric storage heating	1984-1991-Tenement-Cavity Brick-Off Peak Electric storage heating-E-Subgroup 2	1	0.09%
1984-1991-Tower/Slab-Cavity Brick-Off Peak Electric storage heating	1984-1991-Tenement-Cavity Brick-Off Peak Electric storage heating-E-Subgroup 2	1	0.05%
Post 1991-Semi/End Terraced-Sandstone-Oil boiler	Post 1991-Detached-Sandstone-Oil boiler-E	1	0.07%
Post 1991-Semi/End Terraced-Timber-Off Peak Electric storage heating	Post 1991-Detached-Timber-Off Peak Electric storage heating-E-Subgroup 2	1	0.08%
Post 1991-Detached-Sandstone-LPG boiler	Post 1991-Semi/End Terraced-Sandstone-LPG boiler-E	1	0.07%
Post 1991-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-LPG boiler	Post 1991-Semi/End Terraced-Sandstone-LPG boiler-E	1	0.05%
1984-1991-Tenement-Cavity Brick-Electric peak room heater	Post 1991-Tenement-Cavity Brick-Electric peak room heater-E	1	0.06%
Post 1991-4-in-a-block-Cavity Brick-Off Peak Electric storage heating	Post 1991-Tenement-Cavity Brick-Off Peak Electric storage heating-E	1	0.04%
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Solid brick/Cob-Means gas room heater	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler-F-Subgroup 1	2	0.05%
Pre-1919-Detached-Sandstone-Electric peak/off-peak heat pump	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating-F-Subgroup 1	2	0.01%
1919-1964-Detached-Solid brick/Cob-LPG boiler	Pre-1919-Detached-Granite-LPG boiler-F	2	0.09%
Pre-1919-Detached-Solid brick/Cob-Off Peak Electric storage heating	Pre-1919-Detached-Granite-Off Peak Electric storage heating-F-Larger-Subgroup 1	2	0.06%
1919-1964-Semi/End Terraced-Solid	Pre-1919-Semi/End Terraced-	2	0.07%

brick/Cob-Solid fuel boiler	Sandstone-Solid fuel boiler-F-Subgroup 3		
Post 1991-Semi/End Terraced-Solid brick/Cob-Solid fuel boiler	Pre-1919-Semi/End Terraced-Sandstone-Solid fuel boiler-F-Subgroup 3	2	0.07%
Pre-1919-Semi/End Terraced-Solid brick/Cob-Electric peak room heater	Pre-1919-Semi/End Terraced-Sandstone-Electric peak room heater-G	2	0.07%
Pre-1919-Semi/End Terraced-Solid brick/Cob-Off Peak Electric storage heating	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating-F-Subgroup 1	2	0.05%
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Solid brick/Cob-Off Peak Electric storage heating	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating-F-Subgroup 1	2	0.06%
Pre-1919-Semi/End Terraced-System-Electric peak room heater	Pre-1919-Semi/End Terraced-Cavity Brick-Electric peak room heater-G	2	0.01%
1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Solid brick/Cob-Off Peak Electric storage heating	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Off Peak Electric storage heating-E	2	0.06%
1919-1964-Tenement-Cavity Brick-Means gas room heater	Pre-1919-Tenement-Sandstone-Means gas room heater-Lower E	2	0.10%
1919-1964-4-in-a-block-Cavity Brick-Means gas room heater	Pre-1919-Tenement-Sandstone-Means gas room heater-Lower E	2	0.09%
Pre-1919-Tenement-Solid brick/Cob-Electric peak room heater	Pre-1919-Tenement-Sandstone-Electric peak room heater-Upper E-Smaller	2	0.08%
Pre-1919-Tenement-Sandstone-Electric peak/off-peak boiler	Pre-1919-Tenement-Sandstone-Electric peak room heater-F-Larger	2	0.05%
Pre-1919-Flat from converted house-Granite-Electric peak room heater	Pre-1919-Tenement-Sandstone-Electric peak room heater-G-Larger-Subgroup 1	2	0.05%
Pre-1919-4-in-a-block-Sandstone-Solid fuel/wood room heater	Pre-1919-4-in-a-block-Sandstone-Off Peak Electric storage heating-E	2	0.10%
Pre-1919-4-in-a-block-Granite-Oil boiler	Pre-1919-Flat from converted house-Sandstone-Oil boiler-F	2	0.06%
Pre-1919-Flat from converted house-Granite-Oil boiler	Pre-1919-Flat from converted house-Sandstone-Oil boiler-E	2	0.10%
1919-1964-Detached-Solid brick/Cob-Solid fuel boiler	1919-1964-Detached-Solid brick/Cob-Oil boiler-G	2	0.06%
1919-1964-Detached-System-Solid fuel/wood room heater	1919-1964-Detached-System-Solid fuel boiler-G	2	0.01%
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Means gas room heater	1919-1964-Semi/End Terraced-Cavity Brick-Means gas room heater-F-Subgroup 2	2	0.05%
1965-1975-Semi/End Terraced-Timber-Means gas room heater	1919-1964-Semi/End Terraced-Cavity Brick-Means gas room heater-F-Subgroup 2	2	0.09%
1965-1975-Detached-Cavity Brick-Wood boiler	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 2	2	0.09%
1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel/wood room heater	1919-1964-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler-F	2	0.06%
1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Timber-Solid fuel boiler	1919-1964-Semi/End Terraced-Timber-Oil boiler-E	2	0.01%
1919-1964-Semi/End Terraced-System-Electric peak/off-peak boiler	1919-1964-Semi/End Terraced-System-Off Peak Electric storage heating-E-Subgroup 2	2	0.06%

1919-1964-Tenement-Granite-Electric peak/off-peak boiler	1919-1964-Tenement-Granite-Electric peak room heater-F	2	0.04%
1919-1964-Tenement-Cavity Brick-Solid fuel boiler	1919-1964-Tenement-Cavity Brick-Electric peak room heater-E-Subgroup 2	2	0.07%
1919-1964-4-in-a-block-Solid brick/Cob-Off Peak Electric storage heating	1919-1964-4-in-a-block-Cavity Brick-Off Peak Electric storage heating-E	2	0.03%
1919-1964-Tower/Slab-System-Off Peak Electric storage heating	1919-1964-4-in-a-block-Cavity Brick-Off Peak Electric storage heating-E	2	0.10%
1919-1964-Detached-Timber-Solid fuel/wood room heater	1965-1975-Detached-Timber-Oil boiler-F	2	0.01%
1919-1964-Detached-Timber-Solid fuel boiler	1965-1975-Detached-Timber-Oil boiler-E	2	0.05%
1965-1975-Detached-Timber-Electric peak room heater	1965-1975-Detached-Timber-Off Peak Electric storage heating-F	2	0.06%
1965-1975-Semi/End Terraced-Cavity Brick-Solid fuel/wood room heater	1965-1975-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler-E	2	0.06%
1919-1964-Semi/End Terraced-Sandstone-Oil/Gas/Electric warm air	1965-1975-Semi/End Terraced-Timber-Oil/Gas/Electric warm air-E	2	0.04%
1919-1964-Tower/Slab-System-Electric peak room heater	1965-1975-Tenement-Cavity Brick-Electric peak room heater-F-Subgroup 2	2	0.08%
1965-1975-Tower/Slab-System-Electric peak room heater	1965-1975-Tenement-Cavity Brick-Electric peak room heater-F-Subgroup 1	2	0.10%
1976-1983-Detached-Timber-Wood boiler	1976-1983-Detached-Timber-Off Peak Electric storage heating-E	2	0.07%
1976-1983-Detached-Timber-Solid fuel boiler	1976-1983-Semi/End Terraced-Timber-Off Peak Electric storage heating-E-Subgroup 1	2	0.04%
1976-1983-Detached-Timber-Electric peak room heater	1976-1983-Semi/End Terraced-Timber-Off Peak Electric storage heating-E-Subgroup 1	2	0.09%
Post 1991-Detached-Timber-Solid fuel boiler	Post 1991-Detached-Timber-Oil boiler-E	2	0.01%
Post 1991-Tenement-Timber-Electric peak room heater	Post 1991-Tenement-Cavity Brick-Electric peak room heater-E	2	0.07%
Pre-1919-Detached-System-Mains Gas boiler	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler-E	3	0.04%
Pre-1919-Semi/End Terraced-Granite-Solid fuel/wood room heater	Pre-1919-Detached-Granite-Solid fuel/wood room heater-F	3	0.05%
Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Electric peak/off-peak boiler	Pre-1919-Semi/End Terraced-Sandstone-Electric peak/off-peak boiler-E	3	0.04%
Pre-1919-Flat from converted house-Sandstone-Solid fuel boiler	Pre-1919-Tenement-Sandstone-Solid fuel/wood room heater-E	3	0.06%
1919-1964-Detached-Cavity Brick-Solid fuel boiler	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 1	3	0.05%
1965-1975-Detached-Timber-Oil/Gas/Electric warm air	1965-1975-Semi/End Terraced-Timber-Oil/Gas/Electric warm air-E	3	0.05%
1976-1983-Detached-System-Electric peak/off-peak boiler	1976-1983-Semi/End Terraced-Timber-Off Peak Electric storage heating-E-Subgroup 1	3	0.01%
1976-1983-Semi/End Terraced-Solid brick/Cob-Electric peak room heater	1976-1983-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Off Peak Electric storage heating-E	3	0.03%
Post 1991-Tenement-Sandstone-Electric	Post 1991-Tenement-Cavity Brick-Off	3	0.08%

peak room heater	Peak Electric storage heating-E		
1919-1964-Semi/End Terraced-System-Oil/Gas/Electric warm air	House-System-Warm Air central heating-E	3*	0.10%
1919-1964-Tower/Slab-System-Oil/Gas/Electric warm air	House-System-Warm Air central heating-E	3*	0.09%
1965-1975-Mid-terrace/Terrace with passage/Enclosed end-System-Oil/Gas/Electric warm air	House-System-Warm Air central heating-E	3*	0.05%
Pre-1919-Tenement-Granite-Solid fuel/wood room heater	Pre-1919-Tenement-Granite-Solid fuel/wood room heater-G	3*	0.05%
1919-1964-4-in-a-block-Cavity Brick-LPG boiler	1919-1964 4-in-a-block, LPG boiler, Timber, and Cavity Brick, E and F	3*	0.04%
1919-1964-4-in-a-block-Timber-LPG boiler	1919-1964 4-in-a-block, LPG boiler, Timber, and Cavity Brick, E and F	3*	0.04%
1919-1964-Tenement-Cavity Brick-Electric peak/off-peak boiler	Tenement - Cavity - Electric peak/off peak boiler - E	3*	0.10%
Post 1991-Tenement-Cavity Brick-Electric peak/off-peak boiler	Tenement - Cavity - Electric peak/off peak boiler - E	3*	0.10%
Pre-1919-Detached-Sandstone-Community Heating	Pre-1919 house, sandstone, community heating-E	3*	0.01%
Pre-1919-Semi/End Terraced-Sandstone-Community Heating	Pre-1919 house, sandstone, community heating-E	3*	0.01%
Post 1991-Detached-Cavity Brick-Electric peak/off-peak boiler	Post-1991 house with electric heating-E	3*	0.09%
Post 1991-Detached-Cavity Brick-Off Peak Electric storage heating	Post-1991 house with electric heating-E	3*	0.05%
Post 1991-Detached-Timber-Electric peak room heater	Post-1991 house with electric heating-E	3*	0.06%
Post 1991-Detached-System-Electric peak/off-peak heat pump	Post-1991 house with electric heating-E	3*	0.01%
Post 1991-Detached-System-Off Peak Electric storage heating	Post-1991 house with electric heating-E	3*	0.06%
Post 1991-Semi/End Terraced-Sandstone-Off Peak Electric storage heating	Post-1991 house with electric heating-E	3*	0.04%
Post 1991-Semi/End Terraced-Cavity Brick-Electric peak room heater	Post-1991 house with electric heating-E	3*	0.07%
Post 1991-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating	Post-1991 house with electric heating-E	3*	0.09%
1965-1975-Detached-Cavity Brick-Community Heating	1965-1975-Detached-Cavity Brick-Community Heating-E	3*	0.01%
Post 1991-Detached-Cavity Brick-Solid fuel boiler	Post 1991-Detached-Cavity Brick-Solid fuel boiler-E	3*	0.05%
1919-1964-4-in-a-block-Cavity Brick-Solid fuel boiler	1919-1964-4-in-a-block-Cavity Brick-Solid fuel boiler-F	3*	0.02%
Pre-1919-Semi/End Terraced-Solid brick/Cob-Community Heating	Pre-1919-Semi/End Terraced-Solid brick/Cob-Community Heating-E	3*	0.05%
Pre-1919-Flat from converted house-Solid brick/Cob-Solid fuel boiler	Pre-1919-Flat from converted house-Solid brick/Cob-Solid fuel boiler-G	3*	0.01%
1919-1964-Tenement-Solid brick/Cob-Electric peak room heater	1919-1964-Tenement-Solid brick/Cob-Electric peak room heater-G	3*	0.05%

* Indicates the archetypes that were not collapsed into the more prevalent groupings but modelled separately (See Chapter 3).

12 APPENDIX 6: FULL LIST OF TYPOLOGY GROUPS USED

12.1 Table A6.1 provides details of the full list of typology groups used, cross-referencing them with the initial combinations of variables as detailed in Chapter 3.

12.2 As noted previously, the typology groups where created using SAP05 while the modelling of improvements used SAP 2012. The EPC band rating shown in the initial combinations of factors uses SAP05, while the final naming of typology groups uses the SAP 2012 methodology.

12.3 Accompanying this report are details of the 355 individual archetype dwellings that were modelled, giving information on the base position of each dwelling, the appropriateness and impact of individual improvement measures, the packages of measures modelled, and the impact of these packages across a variety of measures.

Table A6.1 Full list of typology groups modelled referenced against initial combination of factors

Ref num	Initial combination Age/Type/Wall/Heating (SAP05 EPC band - size where relevant)	Archetype name – with SAP 2012 EPC Band
1120110	Pre-1919-Detached-Sandstone-Mains Gas boiler (Upper E -Smaller)	Pre-1919-Detached-Sandstone-Mains Gas boiler-Lower E-Smaller
1120115	Pre-1919-Detached-Sandstone-Mains Gas boiler(Upper E - Larger)	Pre-1919-Detached-Sandstone-Mains Gas boiler-Upper E-Larger
1120120	Pre-1919-Detached-Sandstone-Mains Gas boiler(Lower E-Smaller)	Pre-1919-Detached-Sandstone-Mains Gas boiler-F-Smaller-Subgroup 2
1120125	Pre-1919-Detached-Sandstone-Mains Gas boiler(Lower E-Larger)	Pre-1919-Detached-Sandstone-Mains Gas boiler-F-Larger
1120130	Pre-1919-Detached-Sandstone-Mains Gas boiler(F-Smaller)	Pre-1919-Detached-Sandstone-Mains Gas boiler-F-Smaller-Subgroup 1
1120135	Pre-1919-Detached-Sandstone-Mains Gas boiler(F-Larger)	Pre-1919-Detached-Sandstone-Mains Gas boiler-Lower E-Larger
1120510	Pre-1919-Detached-Sandstone-Oil boiler (Upper E-Smaller)	Pre-1919-Detached-Sandstone-Oil boiler-Lower E-Smaller
1120515	Pre-1919-Detached-Sandstone-Oil boiler (Upper E-Larger)	Pre-1919-Detached-Sandstone-Oil boiler-F-Larger-Subgroup 3
1120520	Pre-1919-Detached-Sandstone-Oil boiler (Lower E-Smaller)	Pre-1919-Detached-Sandstone-Oil boiler-F-Smaller-Subgroup 2
1120525	Pre-1919-Detached-Sandstone-Oil boiler (Lower E-Larger)	Pre-1919-Detached-Sandstone-Oil boiler-F-Larger-Subgroup 2
1120530	Pre-1919-Detached-Sandstone-Oil boiler (F-Smaller)	Pre-1919-Detached-Sandstone-Oil boiler-F-Smaller-Subgroup 1
1120535	Pre-1919-Detached-Sandstone-Oil boiler (F-Larger)	Pre-1919-Detached-Sandstone-Oil boiler-F-Larger-Subgroup 1
1120540	Pre-1919-Detached-Sandstone-Oil boiler (G)	Pre-1919-Detached-Sandstone-Oil boiler-F
1130110	Pre-1919-Detached-Granite-Mains Gas boiler (Upper E-Smaller)	Pre-1919-Detached-Granite-Mains Gas boiler-Upper E-Smaller
1130115	Pre-1919-Detached-Granite-Mains Gas boiler (Upper E-Larger)	Pre-1919-Detached-Granite-Mains Gas boiler-Upper E-Larger
1130120	Pre-1919-Detached-Granite-Mains Gas boiler (Lower E-Smaller)	Pre-1919-Detached-Granite-Mains Gas boiler-Lower E-Smaller
1130125	Pre-1919-Detached-Granite-Mains Gas	Pre-1919-Detached-Granite-Mains Gas boiler-F-

	boiler (Lower E-Larger)	Larger-Subgroup 2
1130130	Pre-1919-Detached-Granite-Mains Gas boiler (F-Smaller)	Pre-1919-Detached-Granite-Mains Gas boiler-F-Smaller
1130135	Pre-1919-Detached-Granite-Mains Gas boiler (F-Larger)	Pre-1919-Detached-Granite-Mains Gas boiler-F-Larger-Subgroup 1
1130510	Pre-1919-Detached-Granite-Oil boiler (Upper E-Smaller)	Pre-1919-Detached-Granite-Oil boiler-F-Smaller-Subgroup 2
1130515	Pre-1919-Detached-Granite-Oil boiler (Upper E-Larger)	Pre-1919-Detached-Granite-Oil boiler-Upper E-Larger
1130520	Pre-1919-Detached-Granite-Oil boiler (Lower E-Smaller)	Pre-1919-Detached-Granite-Oil boiler-G-Smaller
1130525	Pre-1919-Detached-Granite-Oil boiler (Lower E-Larger)	Pre-1919-Detached-Granite-Oil boiler-Lower E-Larger
1130530	Pre-1919-Detached-Granite-Oil boiler (F-Smaller)	Pre-1919-Detached-Granite-Oil boiler-F-Smaller-Subgroup 1
1130535	Pre-1919-Detached-Granite-Oil boiler (F-Larger)	Pre-1919-Detached-Granite-Oil boiler-F-Larger
1131710	Pre-1919-Detached-Granite-Off Peak Electric storage heating (Upper E)	Pre-1919-Detached-Granite-Off Peak Electric storage heating-E
1131720	Pre-1919-Detached-Granite-Off Peak Electric storage heating (Lower E-Smaller)	Pre-1919-Detached-Granite-Off Peak Electric storage heating-Upper E-Smaller
1131725	Pre-1919-Detached-Granite-Off Peak Electric storage heating (Lower E-Larger)	Pre-1919-Detached-Granite-Off Peak Electric storage heating-F-Larger-Subgroup 2
1131730	Pre-1919-Detached-Granite-Off Peak Electric storage heating (F-Smaller)	Pre-1919-Detached-Granite-Off Peak Electric storage heating-F-Smaller
1131740	Pre-1919-Detached-Granite-Off Peak Electric storage heating (G-Smaller)	Pre-1919-Detached-Granite-Off Peak Electric storage heating-G-Smaller
1131745	Pre-1919-Detached-Granite-Off Peak Electric storage heating (G-Larger)	Pre-1919-Detached-Granite-Off Peak Electric storage heating-G-Larger
1220110	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler (Upper E-Smaller)	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler-Upper E -Smaller
1220115	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler (Upper E-Larger)	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler-F-Larger-Subgroup 2
1220120	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler (Lower E-Smaller)	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler-Lower E -Smaller-Subgroup 2
1220125	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler (Lower E-Larger)	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler-Upper E-Larger
1220130	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler (F-Smaller)	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler-Lower E -Smaller-Subgroup 1
1220135	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler (F-Larger)	Pre-1919-Semi/End Terraced-Sandstone-Mains Gas boiler-F-Larger-Subgroup 1
1420110	Pre-1919-Tenement-Sandstone-Mains Gas boiler (Upper E-Smaller)	Pre-1919-Tenement-Sandstone-Mains Gas boiler-Lower E-Smaller
1420115	Pre-1919-Tenement-Sandstone-Mains Gas boiler (Upper E-Larger)	Pre-1919-Tenement-Sandstone-Mains Gas boiler-Upper E-Larger
1420120	Pre-1919-Tenement-Sandstone-Mains Gas boiler (Lower E-Smaller)	Pre-1919-Tenement-Sandstone-Mains Gas boiler-F-Smaller
1420125	Pre-1919-Tenement-Sandstone-Mains Gas boiler (Lower E-Larger)	Pre-1919-Tenement-Sandstone-Mains Gas boiler-F-Larger
1421220	Pre-1919-Tenement-Sandstone-Electric peak room heater (Lower E-Smaller)	Pre-1919-Tenement-Sandstone-Electric peak room heater-G-Smaller-Subgroup 2
1421225	Pre-1919-Tenement-Sandstone-Electric peak room heater (Lower E-Larger)	Pre-1919-Tenement-Sandstone-Electric peak room heater-Upper E-Larger
1421230	Pre-1919-Tenement-Sandstone-Electric peak room heater (F-Smaller)	Pre-1919-Tenement-Sandstone-Electric peak room heater-Lower E-Smaller
1421235	Pre-1919-Tenement-Sandstone-Electric peak room heater (F-Larger)	Pre-1919-Tenement-Sandstone-Electric peak room heater-G-Larger-Subgroup 1
1421240	Pre-1919-Tenement-Sandstone-Electric	Pre-1919-Tenement-Sandstone-Electric peak

	peak room heater (G-Smaller)	room heater-G-Smaller-Subgroup 1
1421245	Pre-1919-Tenement-Sandstone-Electric peak room heater (G-Larger)	Pre-1919-Tenement-Sandstone-Electric peak room heater-G-Larger-Subgroup 2
2140110	1919-1964-Detached-Cavity Brick-Mains Gas boiler (Upper E-Smaller)	1919-1964-Detached-Cavity Brick-Mains Gas boiler-Lower E-Smaller
2140115	1919-1964-Detached-Cavity Brick-Mains Gas boiler (Upper E-Larger)	1919-1964-Detached-Cavity Brick-Mains Gas boiler-Lower E-Larger
2140120	1919-1964-Detached-Cavity Brick-Mains Gas boiler (Lower E-Smaller)	1919-1964-Detached-Cavity Brick-Mains Gas boiler-F-Smaller-Subgroup 2
2140125	1919-1964-Detached-Cavity Brick-Mains Gas boiler (Lower E-Larger)	1919-1964-Detached-Cavity Brick-Mains Gas boiler-F-Larger-Subgroup 2
2140130	1919-1964-Detached-Cavity Brick-Mains Gas boiler (F-Smaller)	1919-1964-Detached-Cavity Brick-Mains Gas boiler-F-Smaller-Subgroup 1
2140135	1919-1964-Detached-Cavity Brick-Mains Gas boiler (F-Larger)	1919-1964-Detached-Cavity Brick-Mains Gas boiler-F-Larger-Subgroup 1
2240110	1919-1964-Semi/End Terraced-Cavity Brick-Mains Gas boiler (Upper E-Smaller)	1919-1964-Semi/End Terraced-Cavity Brick-Mains Gas boiler-Upper E-Smaller-Subgroup 2
2240115	1919-1964-Semi/End Terraced-Cavity Brick-Mains Gas boiler (Upper E-Larger)	1919-1964-Semi/End Terraced-Cavity Brick-Mains Gas boiler-Upper E-Larger
2240120	1919-1964-Semi/End Terraced-Cavity Brick-Mains Gas boiler (Lower E-Smaller)	1919-1964-Semi/End Terraced-Cavity Brick-Mains Gas boiler-Upper E-Smaller-Subgroup 1
2240125	1919-1964-Semi/End Terraced-Cavity Brick-Mains Gas boiler (Lower E-Larger)	1919-1964-Semi/End Terraced-Cavity Brick-Mains Gas boiler-F-Larger
2241710	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (Upper E-Smaller)	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating-F-Smaller-Subgroup 3
2241715	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (Upper E-Larger)	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating-Lower E-Larger-Subgroup 2
2241720	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (Lower E-Smaller)	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating-F-Smaller-Subgroup 2
2241725	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (Lower E-Larger)	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating-Lower E-Larger-Subgroup 1
2241730	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (F-Smaller)	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating-F-Smaller-Subgroup 1
2241735	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (F-Larger)	1919-1964-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating-F-Larger
3140110	1965-1975-Detached-Cavity Brick-Mains Gas boiler (Upper E-Smaller)	1965-1975-Detached-Cavity Brick-Mains Gas boiler-Upper E-Smaller
3140115	1965-1975-Detached-Cavity Brick-Mains Gas boiler (Upper E-Larger)	1965-1975-Detached-Cavity Brick-Mains Gas boiler-Upper E-Larger
3140120	1965-1975-Detached-Cavity Brick-Mains Gas boiler (Lower E-Smaller)	1965-1975-Detached-Cavity Brick-Mains Gas boiler-F-Smaller
3140125	1965-1975-Detached-Cavity Brick-Mains Gas boiler (Lower E-Larger)	1965-1975-Detached-Cavity Brick-Mains Gas boiler-F-Larger-Subgroup 2
3140130	1965-1975-Detached-Cavity Brick-Mains Gas boiler (F-Smaller)	1965-1975-Detached-Cavity Brick-Mains Gas boiler-Lower E-Smaller
3140135	1965-1975-Detached-Cavity Brick-Mains Gas boiler (F-Larger)	1965-1975-Detached-Cavity Brick-Mains Gas boiler-F-Larger-Subgroup 1
3240110	1965-1975-Semi/End Terraced-Cavity Brick-Mains Gas boiler (Upper E-Smaller)	1965-1975-Semi/End Terraced-Cavity Brick-Mains Gas boiler-Lower E-Smaller
3240115	1965-1975-Semi/End Terraced-Cavity Brick-Mains Gas boiler (Upper E-Larger)	1965-1975-Semi/End Terraced-Cavity Brick-Mains Gas boiler-Lower E-Larger
3240120	1965-1975-Semi/End Terraced-Cavity	1965-1975-Semi/End Terraced-Cavity Brick-

	Brick-Mains Gas boiler (Lower E-Smaller)	Mains Gas boiler-Upper E-Smaller
3240125	1965-1975-Semi/End Terraced-Cavity Brick-Mains Gas boiler (Lower E-Larger)	1965-1975-Semi/End Terraced-Cavity Brick-Mains Gas boiler-Upper E-Larger
1110110	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler (Upper E)	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler-E
1110120	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler (Lower E)	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler-F-Subgroup 2
1110130	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler (F)	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler-F-Subgroup 1
1110140	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler (G)	Pre-1919-Detached-Solid brick/Cob-Mains Gas boiler-G
1120430	Pre-1919-Detached-Sandstone-LPG boiler (F)	Pre-1919-Detached-Sandstone-LPG boiler-F
1120440	Pre-1919-Detached-Sandstone-LPG boiler (G)	Pre-1919-Detached-Sandstone-LPG boiler-G
1121710	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating (Upper E)	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating-E
1121720	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating (Lower E)	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating-F-Subgroup 2
1121740	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating (G)	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating-G
1210110	Pre-1919-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler (Upper E)	Pre-1919-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler-E
1210120	Pre-1919-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler (Lower E)	Pre-1919-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler-F
1220510	Pre-1919-Semi/End Terraced-Sandstone-Oil boiler (Upper E)	Pre-1919-Semi/End Terraced-Sandstone-Oil boiler-E
1220520	Pre-1919-Semi/End Terraced-Sandstone-Oil boiler (Lower E)	Pre-1919-Semi/End Terraced-Sandstone-Oil boiler-F
1220530	Pre-1919-Semi/End Terraced-Sandstone-Oil boiler (F)	Pre-1919-Semi/End Terraced-Sandstone-Oil boiler-G
1221710	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating (Upper E)	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating-F-Subgroup 2
1221720	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating (Lower E)	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating-E
1221740	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating (G)	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating-G
1230110	Pre-1919-Semi/End Terraced-Granite-Mains Gas boiler (Upper E)	Pre-1919-Semi/End Terraced-Granite-Mains Gas boiler-F-Subgroup 2
1230120	Pre-1919-Semi/End Terraced-Granite-Mains Gas boiler (Lower E)	Pre-1919-Semi/End Terraced-Granite-Mains Gas boiler-F-Subgroup 1
1230130	Pre-1919-Semi/End Terraced-Granite-Mains Gas boiler (F)	Pre-1919-Semi/End Terraced-Granite-Mains Gas boiler-G
1230510	Pre-1919-Semi/End Terraced-Granite-Oil boiler (Upper E)	Pre-1919-Semi/End Terraced-Granite-Oil boiler-E
1230520	Pre-1919-Semi/End Terraced-Granite-Oil boiler (Lower E)	Pre-1919-Semi/End Terraced-Granite-Oil boiler-F-Subgroup 2
1230530	Pre-1919-Semi/End Terraced-Granite-Oil boiler (F)	Pre-1919-Semi/End Terraced-Granite-Oil boiler-F-Subgroup 1
1231710	Pre-1919-Semi/End Terraced-Granite-Off Peak Electric storage heating (Upper E)	Pre-1919-Semi/End Terraced-Granite-Off Peak Electric storage heating-E
1231720	Pre-1919-Semi/End Terraced-Granite-Off Peak Electric storage heating (Lower E)	Pre-1919-Semi/End Terraced-Granite-Off Peak Electric storage heating-F-Subgroup 2
1231730	Pre-1919-Semi/End Terraced-Granite-Off Peak Electric storage heating (F)	Pre-1919-Semi/End Terraced-Granite-Off Peak Electric storage heating-F-Subgroup 1
1420210	Pre-1919-Tenement-Sandstone-Means gas room heater (Upper E)	Pre-1919-Tenement-Sandstone-Means gas room heater-Upper E
1420220	Pre-1919-Tenement-Sandstone-Means gas	Pre-1919-Tenement-Sandstone-Means gas

	room heater (Lower E)	room heater-Lower E
1420230	Pre-1919-Tenement-Sandstone-Means gas room heater (F)	Pre-1919-Tenement-Sandstone-Means gas room heater-F
1421710	Pre-1919-Tenement-Sandstone-Off Peak Electric storage heating (Upper E)	Pre-1919-Tenement-Sandstone-Off Peak Electric storage heating-Upper E
1421720	Pre-1919-Tenement-Sandstone-Off Peak Electric storage heating (Lower E)	Pre-1919-Tenement-Sandstone-Off Peak Electric storage heating-F-Subgroup 2
1421730	Pre-1919-Tenement-Sandstone-Off Peak Electric storage heating (F)	Pre-1919-Tenement-Sandstone-Off Peak Electric storage heating-F-Subgroup 1
1431710	Pre-1919-Tenement-Granite-Off Peak Electric storage heating (Upper E)	Pre-1919-Tenement-Granite-Off Peak Electric storage heating-E-Subgroup 2
1431720	Pre-1919-Tenement-Granite-Off Peak Electric storage heating (Lower E)	Pre-1919-Tenement-Granite-Off Peak Electric storage heating-F
1431730	Pre-1919-Tenement-Granite-Off Peak Electric storage heating (F)	Pre-1919-Tenement-Granite-Off Peak Electric storage heating-E-Subgroup 1
1720110	Pre-1919-Flat from converted house-Sandstone-Mains Gas boiler (Upper E)	Pre-1919-Flat from converted house-Sandstone-Mains Gas boiler-Lower E
1720120	Pre-1919-Flat from converted house-Sandstone-Mains Gas boiler (Lower E)	Pre-1919-Flat from converted house-Sandstone-Mains Gas boiler-Upper E
1720130	Pre-1919-Flat from converted house-Sandstone-Mains Gas boiler (F)	Pre-1919-Flat from converted house-Sandstone-Mains Gas boiler-F
2110110	1919-1964-Detached-Solid brick/Cob-Mains Gas boiler (Upper E)	1919-1964-Detached-Solid brick/Cob-Mains Gas boiler-Lower E-Subgroup 2
2110120	1919-1964-Detached-Solid brick/Cob-Mains Gas boiler (Lower E)	1919-1964-Detached-Solid brick/Cob-Mains Gas boiler-Lower E-Subgroup 3
2110130	1919-1964-Detached-Solid brick/Cob-Mains Gas boiler (F)	1919-1964-Detached-Solid brick/Cob-Mains Gas boiler-Lower E-Subgroup 1
2130110	1919-1964-Detached-Granite-Mains Gas boiler (Upper E)	1919-1964-Detached-Granite-Mains Gas boiler-Lower E-Subgroup 1
2130120	1919-1964-Detached-Granite-Mains Gas boiler (Lower E)	1919-1964-Detached-Granite-Mains Gas boiler-Lower E-Subgroup 2
2140520	1919-1964-Detached-Cavity Brick-Oil boiler (Lower E)	1919-1964-Detached-Cavity Brick-Oil boiler-F-Subgroup 2
2140530	1919-1964-Detached-Cavity Brick-Oil boiler (F)	1919-1964-Detached-Cavity Brick-Oil boiler-F-Subgroup 1
2141710	1919-1964-Detached-Cavity Brick-Off Peak Electric storage heating (Upper E)	1919-1964-Detached-Cavity Brick-Off Peak Electric storage heating-E
2141720	1919-1964-Detached-Cavity Brick-Off Peak Electric storage heating (Lower E)	1919-1964-Detached-Cavity Brick-Off Peak Electric storage heating-F-Subgroup 2
2141730	1919-1964-Detached-Cavity Brick-Off Peak Electric storage heating (F)	1919-1964-Detached-Cavity Brick-Off Peak Electric storage heating-F-Subgroup 1
2210110	1919-1964-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler (Upper E)	1919-1964-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler-E
2210120	1919-1964-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler (Lower E)	1919-1964-Semi/End Terraced-Solid brick/Cob-Mains Gas boiler-F
2240510	1919-1964-Semi/End Terraced-Cavity Brick-Oil boiler (Upper E)	1919-1964-Semi/End Terraced-Cavity Brick-Oil boiler-F-Subgroup 2
2240520	1919-1964-Semi/End Terraced-Cavity Brick-Oil boiler (Lower E)	1919-1964-Semi/End Terraced-Cavity Brick-Oil boiler-F-Subgroup 1
2250110	1919-1964-Semi/End Terraced-Timber-Mains Gas boiler (Upper E)	1919-1964-Semi/End Terraced-Timber-Mains Gas boiler-Lower E-Subgroup 2
2250120	1919-1964-Semi/End Terraced-Timber-Mains Gas boiler (Lower E)	1919-1964-Semi/End Terraced-Timber-Mains Gas boiler-Lower E-Subgroup 1
2260110	1919-1964-Semi/End Terraced-System-Mains Gas boiler (Upper E)	1919-1964-Semi/End Terraced-System-Mains Gas boiler-E
2341710	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Off Peak Electric storage heating (Upper E)	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Off Peak Electric storage heating-E

2341720	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Off Peak Electric storage heating (Lower E)	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Off Peak Electric storage heating-F
2440110	1919-1964-Tenement-Cavity Brick-Mains Gas boiler (Upper E)	1919-1964-Tenement-Cavity Brick-Mains Gas boiler-Upper E-Subgroup 2
2440120	1919-1964-Tenement-Cavity Brick-Mains Gas boiler (Lower E)	1919-1964-Tenement-Cavity Brick-Mains Gas boiler-Upper E-Subgroup 1
2441710	1919-1964-Tenement-Cavity Brick-Off Peak Electric storage heating (Upper E)	1919-1964-Tenement-Cavity Brick-Off Peak Electric storage heating-F-Subgroup 3
2441720	1919-1964-Tenement-Cavity Brick-Off Peak Electric storage heating (Lower E)	1919-1964-Tenement-Cavity Brick-Off Peak Electric storage heating-F-Subgroup 2
2441730	1919-1964-Tenement-Cavity Brick-Off Peak Electric storage heating (F)	1919-1964-Tenement-Cavity Brick-Off Peak Electric storage heating-F-Subgroup 1
2540110	1919-1964-4-in-a-block-Cavity Brick-Mains Gas boiler (Upper E)	1919-1964-4-in-a-block-Cavity Brick-Mains Gas boiler-Upper E
2540120	1919-1964-4-in-a-block-Cavity Brick-Mains Gas boiler (Lower E)	1919-1964-4-in-a-block-Cavity Brick-Mains Gas boiler-Lower E
3140510	1965-1975-Detached-Cavity Brick-Oil boiler (Upper E)	1965-1975-Detached-Cavity Brick-Oil boiler-Lower E
3140520	1965-1975-Detached-Cavity Brick-Oil boiler (Lower E)	1965-1975-Detached-Cavity Brick-Oil boiler-F-Subgroup 2
3140530	1965-1975-Detached-Cavity Brick-Oil boiler (F)	1965-1975-Detached-Cavity Brick-Oil boiler-F-Subgroup 1
3141710	1965-1975-Detached-Cavity Brick-Off Peak Electric storage heating (Upper E)	1965-1975-Detached-Cavity Brick-Off Peak Electric storage heating-E-Subgroup 2
3141720	1965-1975-Detached-Cavity Brick-Off Peak Electric storage heating (Lower E)	1965-1975-Detached-Cavity Brick-Off Peak Electric storage heating-F
3141730	1965-1975-Detached-Cavity Brick-Off Peak Electric storage heating (F)	1965-1975-Detached-Cavity Brick-Off Peak Electric storage heating-E-Subgroup 1
3141740	1965-1975-Detached-Cavity Brick-Off Peak Electric storage heating (G)	1965-1975-Detached-Cavity Brick-Off Peak Electric storage heating-G
3241710	1965-1975-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (Upper E)	1965-1975-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating-E
3241720	1965-1975-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (Lower E)	1965-1975-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating-F-Subgroup 2
3241730	1965-1975-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (F)	1965-1975-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating-F-Subgroup 1
4140510	1976-1983-Detached-Cavity Brick-Oil boiler (Upper E)	1976-1983-Detached-Cavity Brick-Oil boiler-E
4140520	1976-1983-Detached-Cavity Brick-Oil boiler (Lower E)	1976-1983-Detached-Cavity Brick-Oil boiler-F
1110520	Pre-1919-Detached-Solid brick/Cob-Oil boiler (F)	Pre-1919-Detached-Solid brick/Cob-Oil boiler-F
1110530	Pre-1919-Detached-Solid brick/Cob-Oil boiler (Lower E)	Pre-1919-Detached-Solid brick/Cob-Oil boiler-E
1120710	Pre-1919-Detached-Sandstone-Solid fuel boiler (G)	Pre-1919-Detached-Sandstone-Solid fuel boiler-F
1120720	Pre-1919-Detached-Sandstone-Solid fuel boiler (F)	Pre-1919-Detached-Sandstone-Solid fuel boiler-G
1120730	Pre-1919-Detached-Sandstone-Solid fuel boiler (Upper E)	Pre-1919-Detached-Sandstone-Solid fuel boiler-E
1120810	Pre-1919-Detached-Sandstone-Solid fuel/wood room heater (G)	Pre-1919-Detached-Sandstone-Solid fuel/wood room heater-G-Subgroup 2
1120820	Pre-1919-Detached-Sandstone-Solid fuel/wood room heater (F)	Pre-1919-Detached-Sandstone-Solid fuel/wood room heater-G-Subgroup 1
1120830	Pre-1919-Detached-Sandstone-Solid fuel/wood room heater (Upper E)	Pre-1919-Detached-Sandstone-Solid fuel/wood room heater-E

1120920	Pre-1919-Detached-Sandstone-Wood boiler (F)	Pre-1919-Detached-Sandstone-Wood boiler-G
1120930	Pre-1919-Detached-Sandstone-Wood boiler (Lower E)	Pre-1919-Detached-Sandstone-Wood boiler-F
1130410	Pre-1919-Detached-Granite-LPG boiler (G)	Pre-1919-Detached-Granite-LPG boiler-G
1130420	Pre-1919-Detached-Granite-LPG boiler (F)	Pre-1919-Detached-Granite-LPG boiler-F
1130720	Pre-1919-Detached-Granite-Solid fuel boiler (F)	Pre-1919-Detached-Granite-Solid fuel boiler-F
1130810	Pre-1919-Detached-Granite-Solid fuel/wood room heater (G)	Pre-1919-Detached-Granite-Solid fuel/wood room heater-G
1130830	Pre-1919-Detached-Granite-Solid fuel/wood room heater (Lower E)	Pre-1919-Detached-Granite-Solid fuel/wood room heater-F
1130920	Pre-1919-Detached-Granite-Wood boiler (F)	Pre-1919-Detached-Granite-Wood boiler-G
1131210	Pre-1919-Detached-Granite-Electric peak room heater (G)	Pre-1919-Detached-Granite-Electric peak room heater-G
1131220	Pre-1919-Detached-Granite-Electric peak room heater (F)	Pre-1919-Detached-Granite-Electric peak room heater-F
1210530	Pre-1919-Semi/End Terraced-Solid brick/Cob-Oil boiler (Lower E)	Pre-1919-Semi/End Terraced-Solid brick/Cob-Oil boiler-G
1220410	Pre-1919-Semi/End Terraced-Sandstone-LPG boiler (G)	Pre-1919-Semi/End Terraced-Sandstone-LPG boiler-G
1220420	Pre-1919-Semi/End Terraced-Sandstone-LPG boiler (F)	Pre-1919-Semi/End Terraced-Sandstone-LPG boiler-E
1220430	Pre-1919-Semi/End Terraced-Sandstone-LPG boiler (Lower E)	Pre-1919-Semi/End Terraced-Sandstone-LPG boiler-F
1220710	Pre-1919-Semi/End Terraced-Sandstone-Solid fuel boiler (G)	Pre-1919-Semi/End Terraced-Sandstone-Solid fuel boiler-F-Subgroup 2
1220720	Pre-1919-Semi/End Terraced-Sandstone-Solid fuel boiler (F)	Pre-1919-Semi/End Terraced-Sandstone-Solid fuel boiler-F-Subgroup 1
1220730	Pre-1919-Semi/End Terraced-Sandstone-Solid fuel boiler (Upper E)	Pre-1919-Semi/End Terraced-Sandstone-Solid fuel boiler-F-Subgroup 3
1220930	Pre-1919-Semi/End Terraced-Sandstone-Wood boiler (Upper E)	Pre-1919-Semi/End Terraced-Sandstone-Wood boiler-E
1221130	Pre-1919-Semi/End Terraced-Sandstone-Electric peak/off-peak boiler (Upper E)	Pre-1919-Semi/End Terraced-Sandstone-Electric peak/off-peak boiler-E
1221220	Pre-1919-Semi/End Terraced-Sandstone-Electric peak room heater (F)	Pre-1919-Semi/End Terraced-Sandstone-Electric peak room heater-F
1230720	Pre-1919-Semi/End Terraced-Granite-Solid fuel boiler (F)	Pre-1919-Semi/End Terraced-Granite-Solid fuel boiler-F-Subgroup 1
1230730	Pre-1919-Semi/End Terraced-Granite-Solid fuel boiler (Lower E)	Pre-1919-Semi/End Terraced-Granite-Solid fuel boiler-F-Subgroup 2
1241210	Pre-1919-Semi/End Terraced-Cavity Brick-Electric peak room heater (G)	Pre-1919-Semi/End Terraced-Cavity Brick-Electric peak room heater-G
1320130	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Mains Gas boiler (Lower E)	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Mains Gas boiler-F
1320530	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Oil boiler (Upper E)	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Oil boiler-F
1320730	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Solid fuel boiler (Upper E)	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Solid fuel boiler-F
1321730	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Off Peak Electric storage heating (Upper E)	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Off Peak Electric storage heating-E
1330130	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Mains Gas	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Mains Gas

	boiler (Upper E)	boiler-E
1331720	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Off Peak Electric storage heating (F)	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Off Peak Electric storage heating-F-Subgroup 1
1331730	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Off Peak Electric storage heating (Upper E)	Pre-1919-Mid-terrace/Terrace with passage/Enclosed end-Granite-Off Peak Electric storage heating-F-Subgroup 2
1410130	Pre-1919-Tenement-Solid brick/Cob-Mains Gas boiler (Upper E)	Pre-1919-Tenement-Solid brick/Cob-Mains Gas boiler-E
1410220	Pre-1919-Tenement-Solid brick/Cob-Means gas room heater (F)	Pre-1919-Tenement-Solid brick/Cob-Means gas room heater-F
1420820	Pre-1919-Tenement-Sandstone-Solid fuel/wood room heater (F)	Pre-1919-Tenement-Sandstone-Solid fuel/wood room heater-E
1421830	Pre-1919-Tenement-Sandstone-Community Heating (Upper E)	Pre-1919-Tenement-Sandstone-Community Heating-E
1431210	Pre-1919-Tenement-Granite-Electric peak room heater (G)	Pre-1919-Tenement-Granite-Electric peak room heater-F
1431230	Pre-1919-Tenement-Granite-Electric peak room heater (Lower E)	Pre-1919-Tenement-Granite-Electric peak room heater-E
1510130	Pre-1919-4-in-a-block-Solid brick/Cob-Mains Gas boiler (Upper E)	Pre-1919-4-in-a-block-Solid brick/Cob-Mains Gas boiler-E
1520120	Pre-1919-4-in-a-block-Sandstone-Mains Gas boiler (F)	Pre-1919-4-in-a-block-Sandstone-Mains Gas boiler-F
1520130	Pre-1919-4-in-a-block-Sandstone-Mains Gas boiler (Upper E)	Pre-1919-4-in-a-block-Sandstone-Mains Gas boiler-E
1521720	Pre-1919-4-in-a-block-Sandstone-Off Peak Electric storage heating (F)	Pre-1919-4-in-a-block-Sandstone-Off Peak Electric storage heating-F
1530130	Pre-1919-4-in-a-block-Granite-Mains Gas boiler (Upper E)	Pre-1919-4-in-a-block-Granite-Mains Gas boiler-E
1710130	Pre-1919-Flat from converted house-Solid brick/Cob-Mains Gas boiler (Upper E)	Pre-1919-Flat from converted house-Solid brick/Cob-Mains Gas boiler-F
1720530	Pre-1919-Flat from converted house-Sandstone-Oil boiler (Upper E)	Pre-1919-Flat from converted house-Sandstone-Oil boiler-E
1721210	Pre-1919-Flat from converted house-Sandstone-Electric peak room heater (G)	Pre-1919-Flat from converted house-Sandstone-Electric peak room heater-F
1721230	Pre-1919-Flat from converted house-Sandstone-Electric peak room heater (Lower E)	Pre-1919-Flat from converted house-Sandstone-Electric peak room heater-E
1721720	Pre-1919-Flat from converted house-Sandstone-Off Peak Electric storage heating (F)	Pre-1919-Flat from converted house-Sandstone-Off Peak Electric storage heating-G
1721730	Pre-1919-Flat from converted house-Sandstone-Off Peak Electric storage heating (Lower E)	Pre-1919-Flat from converted house-Sandstone-Off Peak Electric storage heating-E
2110520	1919-1964-Detached-Solid brick/Cob-Oil boiler (F)	1919-1964-Detached-Solid brick/Cob-Oil boiler-G
2110530	1919-1964-Detached-Solid brick/Cob-Oil boiler (Lower E)	1919-1964-Detached-Solid brick/Cob-Oil boiler-F
2120130	1919-1964-Detached-Sandstone-Mains Gas boiler (Lower E)	1919-1964-Detached-Sandstone-Mains Gas boiler-E
2120510	1919-1964-Detached-Sandstone-Oil boiler (G)	1919-1964-Detached-Sandstone-Oil boiler-G-Subgroup 2
2120520	1919-1964-Detached-Sandstone-Oil boiler (F)	1919-1964-Detached-Sandstone-Oil boiler-G-Subgroup 1
2120530	1919-1964-Detached-Sandstone-Oil boiler (Upper E)	1919-1964-Detached-Sandstone-Oil boiler-E
2130520	1919-1964-Detached-Granite-Oil boiler (F)	1919-1964-Detached-Granite-Oil boiler-F-Subgroup 1

2130530	1919-1964-Detached-Granite-Oil boiler (Lower E)	1919-1964-Detached-Granite-Oil boiler-F-Subgroup 2
2131710	1919-1964-Detached-Granite-Off Peak Electric storage heating (G)	1919-1964-Detached-Granite-Off Peak Electric storage heating-G
2140410	1919-1964-Detached-Cavity Brick-LPG boiler (G)	1919-1964-Detached-Cavity Brick-LPG boiler-G
2140420	1919-1964-Detached-Cavity Brick-LPG boiler (F)	1919-1964-Detached-Cavity Brick-LPG boiler-F
2160130	1919-1964-Detached-System-Mains Gas boiler (Upper E)	1919-1964-Detached-System-Mains Gas boiler-E
2160510	1919-1964-Detached-System-Oil boiler (G)	1919-1964-Detached-System-Oil boiler-G-Subgroup 2
2160520	1919-1964-Detached-System-Oil boiler (F)	1919-1964-Detached-System-Oil boiler-G-Subgroup 1
2160710	1919-1964-Detached-System-Solid fuel boiler (G)	1919-1964-Detached-System-Solid fuel boiler-G
2160720	1919-1964-Detached-System-Solid fuel boiler (F)	1919-1964-Detached-System-Solid fuel boiler-F-Subgroup 1
2160730	1919-1964-Detached-System-Solid fuel boiler (Upper E)	1919-1964-Detached-System-Solid fuel boiler-F-Subgroup 2
2161710	1919-1964-Detached-System-Off Peak Electric storage heating (G)	1919-1964-Detached-System-Off Peak Electric storage heating-G
2161720	1919-1964-Detached-System-Off Peak Electric storage heating (F)	1919-1964-Detached-System-Off Peak Electric storage heating-F
2220130	1919-1964-Semi/End Terraced-Sandstone-Mains Gas boiler (Lower E)	1919-1964-Semi/End Terraced-Sandstone-Mains Gas boiler-E
2230130	1919-1964-Semi/End Terraced-Granite-Mains Gas boiler (Upper E)	1919-1964-Semi/End Terraced-Granite-Mains Gas boiler-E
2230530	1919-1964-Semi/End Terraced-Granite-Oil boiler (Upper E)	1919-1964-Semi/End Terraced-Granite-Oil boiler-F
2240220	1919-1964-Semi/End Terraced-Cavity Brick-Means gas room heater (F)	1919-1964-Semi/End Terraced-Cavity Brick-Means gas room heater-F-Subgroup 1
2240410	1919-1964-Semi/End Terraced-Cavity Brick-LPG boiler (G)	1919-1964-Semi/End Terraced-Cavity Brick-LPG boiler-G-Subgroup 2
2240430	1919-1964-Semi/End Terraced-Cavity Brick-LPG boiler (Lower E)	1919-1964-Semi/End Terraced-Cavity Brick-LPG boiler-E
2240730	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler (Upper E)	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 2
2241110	1919-1964-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler (G)	1919-1964-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler-G
2251730	1919-1964-Semi/End Terraced-Timber-Off Peak Electric storage heating (Upper E)	1919-1964-Semi/End Terraced-Timber-Off Peak Electric storage heating-E
2261720	1919-1964-Semi/End Terraced-System-Off Peak Electric storage heating (F)	1919-1964-Semi/End Terraced-System-Off Peak Electric storage heating-E-Subgroup 1
2320130	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Mains Gas boiler (Upper E)	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Sandstone-Mains Gas boiler-F
2340130	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Mains Gas boiler (Upper E)	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Mains Gas boiler-E
2410120	1919-1964-Tenement-Solid brick/Cob-Mains Gas boiler (F)	1919-1964-Tenement-Solid brick/Cob-Mains Gas boiler-E-Sugbroup 1
2410130	1919-1964-Tenement-Solid brick/Cob-Mains Gas boiler (Upper E)	1919-1964-Tenement-Solid brick/Cob-Mains Gas boiler-E-Sugbroup 2
2441220	1919-1964-Tenement-Cavity Brick-Electric peak room heater (F)	1919-1964-Tenement-Cavity Brick-Electric peak room heater-E-Subgroup 1
2460130	1919-1964-Tenement-System-Mains Gas boiler (Lower E)	1919-1964-Tenement-System-Mains Gas boiler-E

2541720	1919-1964-4-in-a-block-Cavity Brick-Off Peak Electric storage heating (F)	1919-1964-4-in-a-block-Cavity Brick-Off Peak Electric storage heating-F
2560130	1919-1964-4-in-a-block-System-Mains Gas boiler (Lower E)	1919-1964-4-in-a-block-System-Mains Gas boiler-F
3130530	1965-1975-Detached-Granite-Oil boiler (Lower E)	1965-1975-Detached-Granite-Oil boiler-F-Subgroup 1
3140320	1965-1975-Detached-Cavity Brick-Oil/Gas/Electric warm air (F)	1965-1975-Detached-Cavity Brick-Oil/Gas/Electric warm air-E-Subgroup 1
3141110	1965-1975-Detached-Cavity Brick-Electric peak/off-peak boiler (G)	1965-1975-Detached-Cavity Brick-Electric peak/off-peak boiler-G-Subgroup 2
3141120	1965-1975-Detached-Cavity Brick-Electric peak/off-peak boiler (F)	1965-1975-Detached-Cavity Brick-Electric peak/off-peak boiler-G-Subgroup 1
3150420	1965-1975-Detached-Timber-LPG boiler (F)	1965-1975-Detached-Timber-LPG boiler-F
3151730	1965-1975-Detached-Timber-Off Peak Electric storage heating (Lower E)	1965-1975-Detached-Timber-Off Peak Electric storage heating-E
3160130	1965-1975-Detached-System-Mains Gas boiler (Upper E)	1965-1975-Detached-System-Mains Gas boiler-E
3160410	1965-1975-Detached-System-LPG boiler (G)	1965-1975-Detached-System-LPG boiler-G
3240530	1965-1975-Semi/End Terraced-Cavity Brick-Oil boiler (Lower E)	1965-1975-Semi/End Terraced-Cavity Brick-Oil boiler-F
3241120	1965-1975-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler (F)	1965-1975-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler-F
3250130	1965-1975-Semi/End Terraced-Timber-Mains Gas boiler (Upper E)	1965-1975-Semi/End Terraced-Timber-Mains Gas boiler-E
3261720	1965-1975-Semi/End Terraced-System-Off Peak Electric storage heating (F)	1965-1975-Semi/End Terraced-System-Off Peak Electric storage heating-F
3341130	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak/off-peak boiler (Upper E)	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak/off-peak boiler-F
3341230	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak room heater (Lower E)	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak room heater-E
3341730	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Off Peak Electric storage heating (Upper E)	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Off Peak Electric storage heating-E
3441220	1965-1975-Tenement-Cavity Brick-Electric peak room heater (F)	1965-1975-Tenement-Cavity Brick-Electric peak room heater-F-Subgroup 1
3441230	1965-1975-Tenement-Cavity Brick-Electric peak room heater (Lower E)	1965-1975-Tenement-Cavity Brick-Electric peak room heater-E
3441730	1965-1975-Tenement-Cavity Brick-Off Peak Electric storage heating (Upper E)	1965-1975-Tenement-Cavity Brick-Off Peak Electric storage heating-E
3451730	1965-1975-Tenement-Timber-Off Peak Electric storage heating (Lower E)	1965-1975-Tenement-Timber-Off Peak Electric storage heating-E
4140130	1976-1983-Detached-Cavity Brick-Mains Gas boiler (Upper E)	1976-1983-Detached-Cavity Brick-Mains Gas boiler-E
4140420	1976-1983-Detached-Cavity Brick-LPG boiler (F)	1976-1983-Detached-Cavity Brick-LPG boiler-F
4141730	1976-1983-Detached-Cavity Brick-Off Peak Electric storage heating (Lower E)	1976-1983-Detached-Cavity Brick-Off Peak Electric storage heating-E
4240130	1976-1983-Semi/End Terraced-Cavity Brick-Mains Gas boiler (Upper E)	1976-1983-Semi/End Terraced-Cavity Brick-Mains Gas boiler-E
4241730	1976-1983-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating (Upper E)	1976-1983-Semi/End Terraced-Cavity Brick-Off Peak Electric storage heating- E
4251730	1976-1983-Semi/End Terraced-Timber-Off Peak Electric storage heating (Upper E)	1976-1983-Semi/End Terraced-Timber-Off Peak Electric storage heating-E-Subgroup 2
4351230	1976-1983-Mid-terrace/Terrace with	1976-1983-Mid-terrace/Terrace with

	passage/Enclosed end-Timber-Electric peak room heater (Lower E)	passage/Enclosed end-Timber-Electric peak room heater-E
4441720	1976-1983-Tenement-Cavity Brick-Off Peak Electric storage heating (F)	1976-1983-Tenement-Cavity Brick-Off Peak Electric storage heating-E-Subgroup 1
5140130	1984-1991-Detached-Cavity Brick-Mains Gas boiler (Upper E)	1984-1991-Detached-Cavity Brick-Mains Gas boiler-E
5140420	1984-1991-Detached-Cavity Brick-LPG boiler (F)	1984-1991-Detached-Cavity Brick-LPG boiler-F
5140430	1984-1991-Detached-Cavity Brick-LPG boiler (Lower E)	1984-1991-Detached-Cavity Brick-LPG boiler-E
5140530	1984-1991-Detached-Cavity Brick-Oil boiler (Upper E)	1984-1991-Detached-Cavity Brick-Oil boiler-E
5141730	1984-1991-Detached-Cavity Brick-Off Peak Electric storage heating (Upper E)	1984-1991-Detached-Cavity Brick-Off Peak Electric storage heating-E
5150410	1984-1991-Detached-Timber-LPG boiler (G)	1984-1991-Detached-Timber-LPG boiler-F-Subgroup 2
5150420	1984-1991-Detached-Timber-LPG boiler (F)	1984-1991-Detached-Timber-LPG boiler-F-Subgroup 1
5150430	1984-1991-Detached-Timber-LPG boiler (Lower E)	1984-1991-Detached-Timber-LPG boiler-E
5150530	1984-1991-Detached-Timber-Oil boiler (Upper E)	1984-1991-Detached-Timber-Oil boiler-E
5151120	1984-1991-Detached-Timber-Electric peak/off-peak boiler (F)	1984-1991-Detached-Timber-Electric peak/off-peak boiler-E-Subgroup 1
5151130	1984-1991-Detached-Timber-Electric peak/off-peak boiler (Lower E)	1984-1991-Detached-Timber-Electric peak/off-peak boiler-E-Subgroup 2
5151730	1984-1991-Detached-Timber-Off Peak Electric storage heating (Upper E)	1984-1991-Detached-Timber-Off Peak Electric storage heating-E
5251730	1984-1991-Semi/End Terraced-Timber-Off Peak Electric storage heating (Upper E)	1984-1991-Semi/End Terraced-Timber-Off Peak Electric storage heating-E
5441720	1984-1991-Tenement-Cavity Brick-Off Peak Electric storage heating (F)	1984-1991-Tenement-Cavity Brick-Off Peak Electric storage heating-E-Subgroup 1
6120520	Post 1991-Detached-Sandstone-Oil boiler (F)	Post 1991-Detached-Sandstone-Oil boiler-F
6120530	Post 1991-Detached-Sandstone-Oil boiler (Lower E)	Post 1991-Detached-Sandstone-Oil boiler-E
6130530	Post 1991-Detached-Granite-Oil boiler (Upper E)	Post 1991-Detached-Granite-Oil boiler-E
6140130	Post 1991-Detached-Cavity Brick-Mains Gas boiler (Upper E)	Post 1991-Detached-Cavity Brick-Mains Gas boiler-E
6140530	Post 1991-Detached-Cavity Brick-Oil boiler (Upper E)	Post 1991-Detached-Cavity Brick-Oil boiler-E
6150130	Post 1991-Detached-Timber-Mains Gas boiler (Upper E)	Post 1991-Detached-Timber-Mains Gas boiler-E
6150410	Post 1991-Detached-Timber-LPG boiler (G)	Post 1991-Detached-Timber-LPG boiler-E-Subgroup 1
6150430	Post 1991-Detached-Timber-LPG boiler (Lower E)	Post 1991-Detached-Timber-LPG boiler-E-Subgroup 2
6150530	Post 1991-Detached-Timber-Oil boiler (Upper E)	Post 1991-Detached-Timber-Oil boiler-E
6151720	Post 1991-Detached-Timber-Off Peak Electric storage heating (F)	Post 1991-Detached-Timber-Off Peak Electric storage heating-E-Subgroup 1
6151730	Post 1991-Detached-Timber-Off Peak Electric storage heating (Upper E)	Post 1991-Detached-Timber-Off Peak Electric storage heating-E-Subgroup 2
6230430	Post 1991-Semi/End Terraced-Granite-LPG boiler (Upper E)	Post 1991-Semi/End Terraced-Granite-LPG boiler-E
6431730	Post 1991-Tenement-Granite-Off Peak Electric storage heating (Upper E)	Post 1991-Tenement-Granite-Off Peak Electric storage heating-E

6440430	Post 1991-Tenement-Cavity Brick-LPG boiler (Upper E)	Post 1991-Tenement-Cavity Brick-LPG boiler-E
6621120	Post 1991-Tower/Slab-Sandstone-Electric peak/off-peak boiler (F)	Post 1991-Tower/Slab-Sandstone-Electric peak/off-peak boiler-E
6661730	Post 1991-Tower/Slab-System-Off Peak Electric storage heating (Upper E)	Post 1991-Tower/Slab-System-Off Peak Electric storage heating-E
6720130	Post 1991-Flat from converted house-Sandstone-Mains Gas boiler (Upper E)	Post 1991-Flat from converted house-Sandstone-Mains Gas boiler-E
1121730	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating	Pre-1919-Detached-Sandstone-Off Peak Electric storage heating-F-Subgroup 1
1131735	Pre-1919-Detached-Granite-Off Peak Electric storage heating -Larger	Pre-1919-Detached-Granite-Off Peak Electric storage heating-F-Larger-Subgroup 1
1221210	Pre-1919-Semi/End Terraced-Sandstone-Electric peak room heater	Pre-1919-Semi/End Terraced-Sandstone-Electric peak room heater-G
1221730	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating	Pre-1919-Semi/End Terraced-Sandstone-Off Peak Electric storage heating-F-Subgroup 1
1421210	Pre-1919-Tenement-Sandstone-Electric peak room heater	Pre-1919-Tenement-Sandstone-Electric peak room heater-Upper E-Smaller
1421215	Pre-1919-Tenement-Sandstone-Electric peak room heater	Pre-1919-Tenement-Sandstone-Electric peak room heater-F-Larger
1521730	Pre-1919-4-in-a-block-Sandstone-Off Peak Electric storage heating	Pre-1919-4-in-a-block-Sandstone-Off Peak Electric storage heating-E
1720520	Pre-1919-Flat from converted house-Sandstone-Oil boiler	Pre-1919-Flat from converted house-Sandstone-Oil boiler-F
1730130	Pre-1919-Flat from converted house-Granite-Mains Gas boiler	Pre-1919-Flat from converted house-Granite-Mains Gas boiler-E
2140510	1919-1964-Detached-Cavity Brick-Oil boiler	1919-1964-Detached-Cavity Brick-Oil boiler-F-Subgroup 3
2160530	1919-1964-Detached-System-Oil boiler	1919-1964-Detached-System-Oil boiler-F
2240230	1919-1964-Semi/End Terraced-Cavity Brick-Means gas room heater	1919-1964-Semi/End Terraced-Cavity Brick-Means gas room heater-F-Subgroup 2
2240420	1919-1964-Semi/End Terraced-Cavity Brick-LPG boiler	1919-1964-Semi/End Terraced-Cavity Brick-LPG boiler-G-Subgroup 1
2240720	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler	1919-1964-Semi/End Terraced-Cavity Brick-Solid fuel boiler-E-Subgroup 1
2241120	1919-1964-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler	1919-1964-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler-F
2250530	1919-1964-Semi/End Terraced-Timber-Oil boiler	1919-1964-Semi/End Terraced-Timber-Oil boiler-E
2251720	1919-1964-Semi/End Terraced-Timber-Off Peak Electric storage heating	1919-1964-Semi/End Terraced-Timber-Off Peak Electric storage heating-F
2261730	1919-1964-Semi/End Terraced-System-Off Peak Electric storage heating	1919-1964-Semi/End Terraced-System-Off Peak Electric storage heating-E-Subgroup 2
2341120	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak/off-peak boiler	1919-1964-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak/off-peak boiler-F
2431230	1919-1964-Tenement-Granite-Electric peak room heater	1919-1964-Tenement-Granite-Electric peak room heater-F
2441230	1919-1964-Tenement-Cavity Brick-Electric peak room heater	1919-1964-Tenement-Cavity Brick-Electric peak room heater-E-Subgroup 2
2541730	1919-1964-4-in-a-block-Cavity Brick-Off Peak Electric storage heating	1919-1964-4-in-a-block-Cavity Brick-Off Peak Electric storage heating-E
3140330	1965-1975-Detached-Cavity Brick-Oil/Gas/Electric warm air	1965-1975-Detached-Cavity Brick-Oil/Gas/Electric warm air-E-Subgroup 2
3150520	1965-1975-Detached-Timber-Oil boiler	1965-1975-Detached-Timber-Oil boiler-F
3150530	1965-1975-Detached-Timber-Oil boiler	1965-1975-Detached-Timber-Oil boiler-E
3151720	1965-1975-Detached-Timber-Off Peak	1965-1975-Detached-Timber-Off Peak Electric

	Electric storage heating	storage heating-F
3160420	1965-1975-Detached-System-LPG boiler	1965-1975-Detached-System-LPG boiler-F-Subgroup 2
3160530	1965-1975-Detached-System-Oil boiler	1965-1975-Detached-System-Oil boiler-E
3241130	1965-1975-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler	1965-1975-Semi/End Terraced-Cavity Brick-Electric peak/off-peak boiler-E
3250330	1965-1975-Semi/End Terraced-Timber-Oil/Gas/Electric warm air	1965-1975-Semi/End Terraced-Timber-Oil/Gas/Electric warm air-E
3261730	1965-1975-Semi/End Terraced-System-Off Peak Electric storage heating	1965-1975-Semi/End Terraced-System-Off Peak Electric storage heating-E
3341220	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak room heater	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Electric peak room heater-F
3361730	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-System-Off Peak Electric storage heating	1965-1975-Mid-terrace/Terrace with passage/Enclosed end-System-Off Peak Electric storage heating-E
3441210	1965-1975-Tenement-Cavity Brick-Electric peak room heater	1965-1975-Tenement-Cavity Brick-Electric peak room heater-F-Subgroup 2
3461730	1965-1975-Tenement-System-Off Peak Electric storage heating	1965-1975-Tenement-System-Off Peak Electric storage heating-E
4150130	1976-1983-Detached-Timber-Mains Gas boiler	1976-1983-Detached-Timber-Mains Gas boiler-E
4151730	1976-1983-Detached-Timber-Off Peak Electric storage heating	1976-1983-Detached-Timber-Off Peak Electric storage heating-E
4251720	1976-1983-Semi/End Terraced-Timber-Off Peak Electric storage heating	1976-1983-Semi/End Terraced-Timber-Off Peak Electric storage heating-E-Subgroup 1
4341700	1976-1983-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Off Peak Electric storage heating	1976-1983-Mid-terrace/Terrace with passage/Enclosed end-Cavity Brick-Off Peak Electric storage heating-E
4441730	1976-1983-Tenement-Cavity Brick-Off Peak Electric storage heating	1976-1983-Tenement-Cavity Brick-Off Peak Electric storage heating-E-Subgroup 2
5441730	1984-1991-Tenement-Cavity Brick-Off Peak Electric storage heating	1984-1991-Tenement-Cavity Brick-Off Peak Electric storage heating-E-Subgroup 2
6220430	Post 1991-Semi/End Terraced-Sandstone-LPG boiler	Post 1991-Semi/End Terraced-Sandstone-LPG boiler-E
6441230	Post 1991-Tenement-Cavity Brick-Electric peak room heater	Post 1991-Tenement-Cavity Brick-Electric peak room heater-E
6441730	Post 1991-Tenement-Cavity Brick-Off Peak Electric storage heating	Post 1991-Tenement-Cavity Brick-Off Peak Electric storage heating-E
9990001	1919-1975 - Semi/End Terraced/Tower slab- System – Warm Air central heating	House System Warm Air central heating
9990002	Pre-1919-Tenement-Granite-Solid fuel/wood room heater-G	Pre-1919-Tenement-Granite-Solid fuel/wood room heater-G
9990003	1919-1964-4-in-a-block-Timber and Cavity Brick-LPG boiler-F	1919-1964 4-in-a-block, LPG boiler, Timber, and Cavity Brick, E and F
9990004	Tenement - Cavity - Electric peak/off peak boiler – E	Tenement - Cavity - Electric peak/off peak boiler – E
9990005	Pre-1919 house, sandstone, community heating E	Pre-1919 house, sandstone, community heating E
9990006	Post-1991 house with electric heating	Post-1991 house with electric heating
9990007	1965-1975-Detached-Cavity Brick-Community Heating-E	1965-1975-Detached-Cavity Brick-Community Heating-E
9990008	Post 1991-Detached-Cavity Brick-Solid fuel boiler-F	Post 1991-Detached-Cavity Brick-Solid fuel boiler-F
9990009	1919-1964-4-in-a-block-Cavity Brick-Solid fuel boiler-E	1919-1964-4-in-a-block-Cavity Brick-Solid fuel boiler-E
9990010	Pre-1919-Semi/End Terraced-Solid	Pre-1919-Semi/End Terraced-Solid brick/Cob-

	brick/Cob-Community Heating-E	Community Heating-E
9990011	Pre-1919-Flat from converted house-Solid brick/Cob-Solid fuel boiler-G	Pre-1919-Flat from converted house-Solid brick/Cob-Solid fuel boiler-G
9990012	1919-1964-Tenement-Solid brick/Cob-Electric peak room heater-G	1919-1964-Tenement-Solid brick/Cob-Electric peak room heater-G

13 APPENDIX 7: FUEL COSTS AND SAP AND RDSAP

13.1 All of the fuel costs used in the analysis are from the SAP methodology. These are defined in Table 12 of the respective SAP methodology (i.e. SAP 2009, SAP 2012). Table 12 from SAP 2012 is included here as Table A7.1.

13.2 The prices for all of the fuels in SAP and RdSAP are converted to a p/kWh equivalent. Additionally, some (i.e. gas, bulk LPG, biogas, and the various electricity prices) include a standing charge component; some do not.

13.3 These prices in Table 12 are actually 3-year average of the price / standing charge for the respective fuel collated by the BRE from various sources. Costs from different suppliers of different fuels or from different sources are collected and collated annually and then when SAP is revised they calculate the mean price of the preceding 3 years. The BRE use a 3-year rolling average to remove the volatility of the market from calculation. Prices do go down (occasionally).

13.4 SAP calculates the fuel cost for each fuel use in the home (i.e. main space heating, secondary space heating, water heating, lighting, and the running of fans and pumps associated with the ventilation and heating system) by calculating the delivered energy consumption for each of these fuel uses and then multiplying them by the respective fuel unit price in Table 12. SAP then aggregates these costs and adds them to the relevant standing charges to produce the Total Fuel Cost for the dwelling.

13.5 The treatment of the standing charge component within the calculated fuel costs varies depending on the fuel and circumstance. Although Table 12 shows a standing charge for electricity (£54 in Table 12 of SAP 2012), this standing charge is not included in the SAP Total Fuel Costs. The rationale is that everyone is connected to the electricity mains, so everyone has to pay this amount regardless. Where an off-peak electricity tariff is in use, e.g. electric storage heaters, or the householder still has dual rate meters installed although the heating system has been replaced, SAP only adds the 'additional component' of the standing charge for the respective off-peak tariff to the fuel costs. It is this additional standing charge component for the various off-peak electricity tariffs that is set out in Table 12. Where one of the other fuels with a standing charge is used for heating and hot water (e.g. gas or LPG), then that standing charge component is always added to the fuel bill.

13.6 If there was a mains gas cooker in a dwelling that was heated by an otherwise all electric heating system, then there would be no mains gas standing charge added to the SAP Total Fuel Costs. If this all electric heating was a direct acting system on the standard electricity tariff then there would be no additional standing charge applied to the SAP Total Fuel Costs for the dwelling.

13.7 The SAP Total Fuel Costs *only* comprise the costs associated with space and water heating and lighting in the dwelling. They do NOT include for the costs associated with cooking, appliance use, or (as noted above) the standing charge for standard rate electricity.

13.8 The SAP fuel costs from Table 12 are hard-wired into the SAP programs, and cannot be amended by a user. These costs are not updated annually by BRE. Rather the published versions of the 3-year averages are only amended when a new version of SAP comes out (which is one of the reasons that a revised SAP method is published every few years).

13.9 The result is that the SAP Total Fuel Costs are not the same costs that are paid by a householder. There will be differences in the unit price. The householder will have to pay the full electricity standing charge. The householder will also incur fuel costs for cooking and appliance use (the exclusion of these other costs is an effect of the EU's Energy Performance in Buildings Directive which only set out that member states had to have a methodology that calculated the energy performance of buildings with regard to space and water heating and lighting consumption, and the UK only requiring the SAP methodology to do the minimum to ensure compliance with the EPBD).

13.10 That said, since the introduction of RdSAP 9.91, the software calculates two sets of household fuel costs – one for the calculation of the SAP score (that is, the SAP Total Fuel Costs as set out above), and another that is printed in various places on the EPC that are intended to be more in keeping with what the household is actually paying for fuel for space and water heating and lighting. So, cooking and other appliance costs, as well as the standard rate electricity standing charge are still not included as part of this process.

13.11 To do this, the PCDF now includes two sets of fuel cost tables: those for the calculation of the SAP Total Fuel Costs (to produce the SAP score) and those for the calculation of the household fuel costs (i.e. the 3 year household fuel cost figures that appear on the EPC). They are not the same thing. The basis of the SAP calculation fuel costs are only updated when Table 12 in the respective SAP methodology is amended. The fuel prices used to calculate the household fuel costs on the EPC are updated in the PCDF every six months. See the Table A7.2 over the page for a comparison of the SAP 2009 and SAP 2012 prices versus the household fuel prices for each of the updates since January 2013. Interestingly, the January 2013 household fuel prices are almost identical to the SAP 2012 prices when the SAP 2012 prices are 3-year averages, so you would not expect them to be the same.

13.12 An example of the Energy Costs on the EPC is set out in Figure A7.1 – note they are for 3 years, which is the annual calculated cost multiplied by 3 – there is no inclusion for inflation / changing prices / discounting in this 3 year total, rather, it is a straightforward, simple multiplication of the calculated annual costs at the time the EPC is produced. If you redo the assessment in 6 months' time it is a possibility that these published prices may have changed: the longer the gap between reassessing these prices the more likely they will be different. However, the rating will not change.

13.13 At present the effect of feed-in tariffs has not been factored into SAP. This is under consideration and the UK government will consult on proposals.

Figure A7.1: Energy Costs on the EPC

Estimated energy costs for your home for 3 years*	£2,493	See your recommendations report for more information
Over 3 years you could save*	£513	

Estimated energy costs for this home

	Current energy costs	Potential energy costs
Heating	£1,890 over 3 years	£1,485 over 3 years
Hot water	£300 over 3 years	£300 over 3 years
Lighting	£303 over 3 years	£195 over 3 years
Totals	**£2,493**	**£1,980**

13.14 Further, there is a difference in the basis of the calculation of the SAP Total Fuel Costs and the Household Fuel Costs. The SAP Total Fuel Costs are calculated for the average UK climate, while the Household Fuel Costs now take account of local climatic variables (i.e. degree day region and height above sea level) – so even if they used the same fuel price for each fuel, the Household Fuel Costs would vary as you move the dwelling around the country while the SAP Total Fuel Costs would not change.

13.15 Neither set of Fuel Cost calculations takes account of actual occupancy. The number of occupants is derived from the floor area of the dwelling.

13.16 Neither set of Fuel Cost calculations take account of different heating patterns. Both assume the dwelling is heated to what is referred to as the Standard Heating Regime, a demand temperature of 21^{o}C in the main living area and 18^{o}C in the rest of the dwelling for 9 hours in 2 periods (2 hours in the morning between 7 and 9AM) during Monday to Friday, and 16 hours in a single period (between 7AM and 11PM) at the weekends.

13.17 Occupant behaviour with regards to actual house temperatures, use of heating, or extent of heating their home, or the appliances actually used are not included in the calculation of either set of fuel costs.

Table A7.1: SAP Table 12: Fuel Prices, emission factors and primary energy factors[87]

Table 12: Fuel prices, emission factors and primary energy factors

Fuel	Standing charge, £ (a)	Unit price p/kWh	Emissions kg CO_2 per kWh (b)	Primary energy factor	Fuel code
Gas:					
mains gas	120	3.48	0.216	1.22	1
bulk LPG	70	7.60	0.241	1.09	2
bottled LPG		10.30	0.241	1.09	3
LPG subject to Special Condition 18 (c)	120	3.48	0.241	1.09	9
biogas (including anaerobic digestion)	70	7.60	0.098	1.10	7
Oil:					
heating oil		5.44	0.298	1.10	4
biodiesel from any biomass source (d)		7.64	0.123	1.06	71
biodiesel from vegetable oil only (e)		7.64	0.083	1.01	73
appliances able to use mineral oil or biodiesel		5.44	0.298	1.10	74
B30K (f)		6.10	0.245	1.09	75
bioethanol from any biomass source		47.0	0.140	1.08	76
Solid fuel: (g)					
house coal		3.67	0.394	1.00	11
anthracite		3.64	0.394	1.00	15
manufactured smokeless fuel		4.61	0.433	1.21	12
wood logs		4.23	0.019	1.04	20
wood pellets (in bags for secondary heating)		5.81	0.039	1.26	22
wood pellets (bulk supply for main heating)		5.26	0.039	1.26	23
wood chips		3.07	0.016	1.12	21
dual fuel appliance (mineral and wood)		3.99	0.226	1.02	10
Electricity: (a)					
standard tariff	54	13.19	0.519	3.07	30
7-hour tariff (high rate) (h)	24	15.29	0.519	3.07	32
7-hour tariff (low rate) (h)		5.50	0.519	3.07	31
10-hour tariff (high rate) (h)	23	14.68	0.519	3.07	34
10-hour tariff (low rate) (h)		7.50	0.519	3.07	33
18-hour tariff (high rate) (h)	40	13.67	0.519	3.07	38
18-hour tariff (low rate) (h)		7.41	0.519	3.07	40
24-hour heating tariff	70	6.61	0.519	3.07	35
electricity sold to grid		13.19 (i)	0.519	3.07	36
electricity displaced from grid			0.519 (i)	3.07 (i)	37
electricity, any tariff (j)					39
Community heating schemes: (k)	120 (l)				
heat from boilers – mains gas		4.24	0.216	1.22	51
heat from boilers – LPG		4.24	0.241	1.09	52
heat from boilers – oil		4.24	0.331 (m)	1.10	53
heat from boilers that can use mineral oil or biodiesel		4.24	0.331	1.10	56
heat from boilers using biodiesel from any biomass source		4.24	0.123	1.06	57
heat from boilers using biodiesel from vegetable oil only		4.24	0.083	1.01	58
heat from boilers – B30D (f)		4.24	0.269	1.09	55
heat from boilers – coal		4.24	0.380 (n)	1.00	54
heat from electric heat pump		4.24	0.519	3.07	41
heat from boilers – waste combustion		4.24	0.047	1.23	42
heat from boilers – biomass		4.24	0.031 (o)	1.01	43
heat from boilers – biogas (landfill or sewage gas)		4.24	0.098	1.10	44
waste heat from power station		2.97	0.058 (p)	1.34	45
geothermal heat source		2.97	0.041	1.24	46
heat from CHP		2.97	as above (q)	as above (q)	48
electricity generated by CHP			0.519 (i)	3.07 (i)	49
electricity for pumping in distribution network			0.519	3.07	50

Energy Cost Deflator (r) = 0.42

[87] Source: (2014) The Government's Standard Assessment Procedure for Energy Rating of Dwellings (2012 edition), p231, BRE, Garston

Table A7.2: Comparison of Household Fuel Prices in PCDF and SAP 2009 and SAP 2012 Table 12 prices[88]

	From July 2014		From January 2014		From July 2013		From January 2013		SAP 2012 Table 12		SAP 2009 Table 12	
Fuel	**Standing £**	**Unit price p/kWh**	**Standing £**	**Unit price p/kWh**	**Standing £**	**Unit price p/kWh**	**Standing £**	**Unit price p/kWh**	**Standing £**	**Unit price p/kWh**	**Standing £**	**Unit price p/kWh**
Mains gas	113	4.04	116	3.84	119	3.64	120	3.48	120	3.48	106	3.10
Bulk LPG	70	8.40	70	8.27	70	8.04	70	7.60	70	7.60	70	5.73
Bottled LPG		10.90		10.89		10.59		10.30		9.87		8.34
Heating oil		5.87		5.95		5.74		5.44		5.44		4.06
House coal		3.88		3.78		3.71		3.67		3.67		2.97
Anthracite		3.91		3.85		3.76		3.67		3.64		2.86
Manufactured smokeless fuel		4.90		4.78		4.69		4.61		4.61		3.73
Wood logs		4.65		4.65		4.60		4.23		4.23		3.42
Wood pellets secondary		6.16		6.02		5.88		5.81		5.81		5.45
Wood pellets main heating		5.57		5.45		5.32		5.26		5.26		4.93
Wood chips		3.25		3.17		3.11		3.07		3.07		2.49
Dual fuel appliance		4.22		4.12		4.04		3.99		3.99		3.21
Standard tariff		14.46		14.02		13.59		13.19	54	13.19		11.46
7-hour tariff high rate	16	17.06	20	16.46	23	15.85	25	15.29	24	15.29	27	12.52
7-hour tariff low rate		6.26		6.00		5.74		5.50		5.50		4.78
10-hour tariff high rate	16	16.38	19	15.81	22	15.22	23	14.68	23	14.68	18	11.83
10-hour tariff low rate		8.54		8.18		7.83		7.50		7.50		6.17
24-hour heating tariff	76	7.35	74	7.05	72	6.84	70	6.61	70	6.61	57	5.46
Electricity sold to grid		14.46		14.02		13.59		13.19		13.19		11.46
Community	113	4.93	116	4.68	119	4.44	120	4.24	120	4.24	106	3.78
Community CHP		3.45		3.28		3.11		2.97		2.97		2.65

[88] Collated from the PCDF / SAP 2009 / SAP 2012. Acknowledgment to Scott Restrick, Energy Action Scotland for the initial work on collating the data included in this table. Additional data was added subsequently by the authors of this report.

14 APPENDIX 8: ADDITIONAL TABLES

Target stock by selected dwelling characteristics

Table A8.1: Summary of private sector dwellings in EPC bands EFG by type

			SAP 2005			SAP 2012		
	Sample size	**% of all dwellings in EFG**	**SAP Band E**	**SAP Band F**	**SAP Band G**	**SAP Band E**	**SAP Band F**	**SAP Band G**
Detached	930	45%	126,091 (70%)	44,601 (25%)	10,192 (6%)	88,392 (49%)	74,764 (41%)	17,729 (10%)
Semi-detached	392	23%	80,400 (87%)	9,806 (11%)	2,156 (2%)	59,185 (64%)	29,112 (32%)	4,064 (4%)
Mid-terrace & terrace with passage	75	5%	16,043 (82%)	3,164 (16%)	380 (2%)	9,161 (47%)	9,692 (49%)	734 (4%)
End-terrace	131	8%	25,636 (84%)	4,132 (14%)	714 (2%)	19,346 (63%)	10,138 (33%)	1,098 (4%)
Enclosed end	3	0%	387 (91%)	38 (9%)	0 (0%)	387 (91%)	38 (9%)	0 (0%)
Tenement	159	13%	38,436 (72%)	11,398 (21%)	3,371 (6%)	35,212 (66%)	12,382 (23%)	5,612 (11%)
4-in-a-block	42	2%	8,404 (87%)	1,228 (13%)	0 (0%)	7,643 (79%)	1,989 (21%)	0 (0%)
Tower/slab	10	1%	1,885 (55%)	796 (23%)	724 (21%)	2,287 (67%)	1,117 (33%)	0 (0%)
Flat from converted house	44	3%	8,718 (83%)	1,191 (11%)	658 (6%)	8,328 (79%)	1,800 (17%)	439 (4%)
Total	1786	100%	306,000 (76%)	76,353 (19%)	18,195 (5%)	229,840 (57%)	141,032 (35%)	29,676 (7%)

Table A8.2: Summary of private sector dwellings in EPC bands EFG by dwelling age

		SAP 2005				SAP 2012		
	Sample size	% of all dwellings in EFG	SAP Band E	SAP Band F	SAP Band G	SAP Band E	SAP Band F	SAP Band G
Pre 1919	746	46%	124,143 (68%)	47,113 (26%)	11,976 (7%)	75,388 (41%)	85,158 (46%)	22,685 (12%)
1919 - 1929	84	4%	13,521 (80%)	2,621 (15%)	904 (5%)	9,760 (57%)	5,312 (31%)	1,975 (12%)
1930 - 1949	227	12%	42,318 (86%)	5,149 (10%)	1,956 (4%)	33,965 (69%)	13,668 (28%)	1,791 (4%)
1950 - 1964	231	12%	41,420 (84%)	6,815 (14%)	895 (2%)	31,228 (64%)	17,250 (35%)	651 (1%)
1965 - 1975	274	14%	47,187 (82%)	8,317 (14%)	2,022 (4%)	38,968 (68%)	16,169 (28%)	2,389 (4%)
1976 - 1983	82	4%	13,045 (84%)	2,250 (15%)	185 (1%)	13,838 (89%)	1,457 (9%)	185 (1%)
1984 - 1991	60	3%	10,080 (83%)	2,016 (17%)	61 (1%)	10,843 (89%)	1,314 (11%)	0 (0%)
1992 - 1998	43	2%	7,750 (90%)	879 (10%)	0 (0%)	8,131 (94%)	498 (6%)	0 (0%)
1999 - 2002	12	1%	1,708 (63%)	996 (37%)	0 (0%)	2,500 (92%)	204 (8%)	0 (0%)
2003 - 2007	20	1%	3,391 (94%)	199 (6%)	0 (0%)	3,590 (100%)	0 (0%)	0 (0%)
2008 onwards	7	0%	1,436 (88%)	0 (0%)	195 (12%)	1,631 (100%)	0 (0%)	0 (0%)
Total	1786	100%	306,000 (76%)	76,353 (19%)	18,195 (5%)	229,840 (57%)	141,032 (35%)	29,676 (7%)

Table A8.3: Summary of private sector dwellings in EPC bands EFG by wall type

		SAP 2005				SAP 2012		
	Sample size	% of all dwellings in EFG	SAP Band E	SAP Band F	SAP Band G	SAP Band E	SAP Band F	SAP Band G
Solid brick	108	7%	20,947 (78%)	4,996 (19%)	871 (3%)	15,512 (58%)	8,775 (33%)	2,527 (9%)
Cavity brick	664	36%	122,073 (85%)	18,190 (13%)	4,128 (3%)	97,903 (68%)	41,986 (29%)	4,502 (3%)
Sandstone	533	29%	81,645 (71%)	26,827 (23%)	7,147 (6%)	55,251 (48%)	48,620 (42%)	11,748 (10%)
Granite/whinstone	229	17%	45,940 (66%)	18,564 (27%)	4,697 (7%)	25,504 (37%)	33,735 (49%)	9,962 (14%)
Timber	149	6%	20,690 (81%)	4,610 (18%)	256 (1%)	21,784 (85%)	3,772 (15%)	0 (0%)
Cob (earth)	5	0%	445 (71%)	179 (29%)	0 (0%)	583 (94%)	40 (6%)	0 (0%)
System	98	5%	14,259 (78%)	2,986 (16%)	1,097 (6%)	13,304 (73%)	4,102 (22%)	936 (5%)
Total	1786	100%	306,000 (76%)	76,353 (19%)	18,195 (5%)	229,840 (57%)	141,032 (35%)	29,676 (7%)

Table A8.4: Summary of private sector dwellings in EPC bands EFG by main heating type

			SAP 2005			SAP 2012		
	Sample size	**% of all dwellings in EFG**	**SAP Band E**	**SAP Band F**	**SAP Band G**	**SAP Band E**	**SAP Band F**	**SAP Band G**
Mains Gas boiler	615	40%	152,328 (95%)	7,924 (5%)	340 (0%)	123,219 (77%)	36,500 (23%)	872 (1%)
Mains gas room heater	20	2%	4,625 (73%)	1,710 (27%)	0 (0%)	2,891 (46%)	3,444 (54%)	0 (0%)
Mains gas warm air	7	0%	1,919 (100%)	0 (0%)	0 (0%)	1,919 (100%)	0 (0%)	0 (0%)
LPG boiler	74	4%	4,382 (26%)	7,589 (45%)	4,880 (29%)	5,589 (33%)	5,904 (35%)	5,358 (32%)
Oil boiler	423	19%	58,829 (76%)	18,726 (24%)	278 (0%)	26,545 (34%)	44,263 (57%)	7,025 (9%)
Oil warm air	2	0%	193 (100%)	0 (0%)	0 (0%)	193 (100%)	0 (0%)	0 (0%)
Solid fuel boiler	61	3%	5,910 (53%)	4,312 (38%)	1,014 (9%)	4,577 (41%)	5,646 (50%)	1,013 (9%)
Solid fuel room heater	16	1%	1,027 (30%)	1,616 (47%)	808 (23%)	1,334 (39%)	644 (19%)	1,473 (43%)
Wood boiler	13	1%	2,089 (78%)	599 (22%)	0 (0%)	1,164 (43%)	965 (36%)	559 (21%)
Wood room heater	5	0%	149 (12%)	808 (64%)	299 (24%)	0 (0%)	339 (27%)	918 (73%)
Electric peak boiler	13	1%	448 (12%)	2,272 (59%)	1,102 (29%)	1,465 (38%)	1,255 (33%)	1,102 (29%)
Electric peak room heater	86	6%	8,419 (33%)	9,766 (38%)	7,184 (28%)	10,957 (43%)	6,109 (24%)	8,301 (33%)
Electric peak Heat Pump	1	0%	43 (100%)	0 (0%)	0 (0%)	43 (100%)	0 (0%)	0 (0%)
Off peak Electric boiler	19	1%	3,459 (80%)	888 (20%)	0 (0%)	2,247 (52%)	1,483 (34%)	617 (14%)
Off peak Electric warm air	4	0%	417 (44%)	540 (56%)	0 (0%)	957 (100%)	0 (0%)	0 (0%)
Off peak Electric Heat pump	1	0%	0 (0%)	47 (100%)	0 (0%)	0 (0%)	47 (100%)	0 (0%)
Off Peak Electric storage heating	421	21%	61,009 (74%)	19,557 (24%)	2,291 (3%)	45,986 (55%)	34,434 (42%)	2,438 (3%)
Community Heating	5	0%	756 (100%)	0 (0%)	0 (0%)	756 (100%)	0 (0%)	0 (0%)
Total	1786	100%	306,000 (76%)	76,353 (19%)	18,195 (5%)	229,840 (57%)	141,032 (35%)	29,676 (7%)

Additional tables on individual measures

Table A8.5 Number of measures modelled (possible to implement) by rurality, tenure and EPC banding.

	Rurality				Tenure				EPC banding					
	Rural		Urban		Owner-occupied		Private Rented		G		F		E	
	N	%age	N	%age	N	%age	N	%age	N	%age	N	%age	N	%age
M1: Loft Insulation, Including Top Up	130,775	78%	169,894	73%	246,924	76%	53,745	69%	24,892	84%	112,885	80%	162,893	71%
M2: Flat Roof Insulation	24,959	15%	21,659	9%	32,027	10%	14,590	19%	6,084	21%	25,929	18%	14,605	6%
M3: Room In The Roof Insulation	60,737	36%	57,334	25%	99,730	31%	18,342	24%	9,834	33%	64,211	46%	44,026	19%
M4: Cavity Wall Insulation	67,672	41%	114,625	49%	153,311	47%	28,986	37%	12,444	42%	71,904	51%	97,948	43%
M5: Solid Wall Insulation	107,781	65%	121,980	52%	175,795	54%	53,967	69%	24,937	84%	97,847	69%	106,978	47%
M6: Floor Insulation	159,008	95%	185,764	80%	290,077	90%	54,695	70%	25,918	87%	129,819	92%	189,034	82%
M7: Double Glazing To 1.8	38,095	23%	65,425	28%	73,642	23%	29,878	38%	13,567	46%	48,066	34%	41,887	18%
M8: Secondary Glazing To 2.4	37,212	22%	62,058	27%	71,970	22%	27,300	35%	9,928	33%	48,804	35%	40,538	18%
M9: Triple Glazing To 1.4	136,825	82%	177,913	76%	247,054	77%	67,684	87%	26,667	90%	118,889	84%	169,183	74%
M10: Insulated External Doors	165,332	99%	232,024	99%	320,235	99%	77,121	99%	29,459	99%	140,957	100%	226,940	99%
M11: Hot Water Tank Jacket 80Mm	85,771	51%	130,311	56%	171,920	53%	44,162	57%	19,437	65%	83,709	59%	112,937	49%
M12: Draughtproof windows & doors	137,864	83%	178,210	76%	249,715	77%	66,358	85%	26,667	90%	119,461	85%	169,945	74%
M13: Baffle / Damper To Open Fire	100,242	60%	81,466	35%	148,504	46%	33,204	43%	11,456	39%	83,408	59%	86,843	38%
M14: Replace Gas Boiler With Condensing Boiler 88%	16,101	10%	125,758	54%	125,057	39%	16,803	22%	872	3%	32,369	23%	108,618	47%
M15: Replace Oil/LPG Boiler to 90%	66,033	40%	5,483	2%	55,337	17%	16,178	21%	10,696	36%	41,652	30%	19,168	8%
M16: Full Gas CH System inc controls	1,889	1%	12,485	5%	8,922	3%	5,452	7%	1,417	5%	5,049	4%	7,908	3%
M17: Full Oil/LPG CH System inc Controls	7,691	5%	581	0%	4,877	2%	3,396	4%	3,001	10%	4,671	3%	601	0%
M18: Full Biomass Central Heating System Inc Controls	13,008	8%	1,972	1%	9,848	3%	5,132	7%	3,709	12%	7,239	5%	4,031	2%

	Rurality				Tenure				EPC banding					
	Rural		Urban		Owner-occupied		Private Rented		G		F		E	
M19: Fan Elec Storage Heaters With Auto Charge Control	47,056	28%	68,145	29%	83,136	26%	32,065	41%	14,589	49%	41,898	30%	58,715	26%
M20: Quantum Storage Heaters	48,651	29%	70,783	30%	85,789	27%	33,645	43%	14,589	49%	43,863	31%	60,983	27%
M21: Full Elec Radiator System Inc Controls - Off Peak	339	0%	2,074	1%	1,257	0%	1,155	1%	0	0%	1,572	1%	840	0%
M22: Air Source Heat Pump	5,594	3%	5,291	2%	8,568	3%	2,318	3%	3,034	10%	5,561	4%	2,291	1%
M23: Ground Source Heat Pump	7,529	5%	3,271	1%	7,417	2%	3,383	4%	2,921	10%	5,156	4%	2,722	1%
M24: Room Thermostat	67,227	40%	80,159	34%	124,133	38%	23,253	30%	11,140	38%	47,932	34%	88,314	38%
M25: Programmer For Heating System	4,070	2%	2,131	1%	3,053	1%	3,148	4%	775	3%	3,899	3%	1,527	1%
M26: Trvs	15,911	10%	41,189	18%	49,813	15%	7,288	9%	5,494	19%	19,018	13%	32,588	14%
M27: Full Controls Package	12,477	7%	3,228	1%	10,748	3%	4,956	6%	3,889	13%	7,813	6%	4,004	2%
M28: Auto Charge Control	11,547	7%	18,084	8%	22,876	7%	6,755	9%	1,203	4%	11,787	8%	16,641	7%
M29: Solar Thermal $4m^2$	119,468	72%	127,200	54%	202,969	63%	43,698	56%	19,318	65%	102,014	72%	125,335	55%
M30: Pv 2Kwp	122,627	73%	133,047	57%	210,219	65%	45,455	58%	19,318	65%	104,326	74%	132,030	57%
M31: 2M Diameter Wind Turbine On Roof	161,270	97%	185,038	79%	291,220	90%	55,087	71%	25,630	86%	127,771	91%	192,907	84%
M32: 5M Wind Turbine On Stand-Alone Mast	160,023	96%	166,228	71%	276,403	86%	49,849	64%	23,769	80%	124,327	88%	178,156	78%
M33: Low Energy Lighting 100%	140,075	84%	215,967	92%	288,755	89%	67,287	87%	25,373	85%	120,698	86%	209,972	91%
M34: Cylinder Stat for HW Cylinder	34,058	20%	23,189	10%	47,290	15%	9,957	13%	6,883	23%	28,812	20%	21,553	9%
M35: Air To Air Heat Pump	44,038	26%	66,925	29%	78,723	24%	32,240	41%	11,639	39%	41,201	29%	58,124	25%
M36: Replace Secondary Heating With One More Efficient	61,424	37%	35,133	15%	74,075	23%	22,482	29%	11,232	38%	53,359	38%	31,966	14%
M37: Elec CPSU With Radiators And Controls On E18 Tariff	1,941	1%	0	0%	1,620	1%	321	0%	1,941	7%	0	0%	0	0%
M38: Switch Electricity Tariff	14,621	9%	24,093	10%	29,534	9%	9,181	12%	2,340	8%	7,577	5%	28,796	13%

Table A8.6 Summary of individual measures

	Mean change in SAP	Mean change in annual fuel costs	Mean change in CO_{2e}	Mean change in Primary Energy	Mean change in Delivered Energy	Mean capital costs	Cost per SAP point increase	Cost per fuel savings (pay back)	CO_{2e} saved per £	PE saved per £	DE saved per £	Dwellings modelled
M11: Hot Water Tank Jacket 80Mm	1.2	£31	159	790	425	£23	£19	1	7.1	35.1	18.9	216,082
M33: Low Energy Lighting 100%	1.0	£29	94	630	109	£32	£33	1	2.9	19.5	3.4	356,043
M38: Switch Electricity Tariff	5.6	£148	257	1,628	469	£200	£36	1	1.3	8.1	2.3	38,714
M1: Loft Insulation, inc Top Up	5.3	£165	1,003	5,143	3,587	£350	£66	2	2.9	14.7	10.3	300,669
M26: Trvs	2.4	£82	508	2,432	2,030	£175	£74	2	2.9	13.9	11.6	57,100
M27: Full Controls Package	4.1	£187	1,067	4,116	3,501	£402	£97	2	2.7	10.2	8.7	15,705
M24: Room Thermostat	2.4	£79	444	2,246	1,767	£200	£85	3	2.2	11.2	8.8	147,386
M36: Replace Secondary Heating With One More Efficient	5.2	£185	1,485	5,346	4,476	£481	£93	3	3.1	11.1	9.3	96,558
M13: Baffle / Damper To Open Fire	.9	£29	187	916	634	£85	£94	3	2.2	10.8	7.5	181,708
M34: Cylinder Stat For Hot Water Cylinder	2.1	£69	373	1,801	1,557	£300	£146	4	1.2	6.0	5.2	57,247
M3: Room In The Roof Insulation	13.0	£454	2,778	13,767	10,266	£2,100	£162	5	1.3	6.6	4.9	118,072
M19: Fan Elec Storage Heaters With Auto Charge Control	8.3	£220	85	-538	695	£1,180	£142	5	.1	-.5	.6	115,201
M4: Cavity Wall Insulation	6.6	£183	1,160	5,812	3,934	£1,000	£153	5	1.2	5.8	3.9	182,296
M28: Auto Charge Control	1.2	£34	259	1,512	506	£200	£173	6	1.3	7.6	2.5	29,631
M20: Quantum Storage Heaters	14.0	£359	1,263	6,243	2,997	£2,380	£170	7	.5	2.6	1.3	119,434
M12: Draughtproof Windows And Doors	.5	£15	89	479	313	£100	£216	7	.9	4.8	3.1	316,074
M37: Elec CPSU With Radiators And Controls On E18 Tariff	17.0	£569	-3,537	-29,226	6,442	£5,000	£294	9	-.7	-5.8	1.3	1,941
M16: Full Gas Central Heating System Inc Controls	26.2	£565	2,782	16,247	1,937	£5,000	£191	9	.6	3.2	.4	14,374
M15: Replace Oil/LPG Boiler to 90%	7.4	£286	1,401	5,496	4,815	£2,600	£350	9	.5	2.1	1.9	71,515
M17: Full Oil/LPG Central Heating	15.1	£466	2,844	17,016	17,679	£5,000	£332	11	.6	3.4	3.5	8,273

	Mean change in SAP	Mean change in annual fuel costs	Mean change in CO_{2e}	Mean change in Primary Energy	Mean change in Delivered Energy	Mean capital costs	Cost per SAP point increase	Cost per fuel savings (pay back)	CO_{2e} saved per £	PE saved per £	DE saved per £	Dwellings modelled
System Inc Controls												
M14: Replace Gas Boiler With Condensing Boiler 88%	8.3	£236	1,483	8,243	6,760	£2,600	£313	11	.6	3.2	2.6	141,859
M21: Full Elec Radiator System Inc Controls - Off Peak	10.3	£227	169	1,001	330	£2,600	£252	11	.1	.4	.1	2,412
M6: Floor Insulation	2.8	£87	542	2,736	1,754	£1,000	£351	11	.5	2.7	1.8	344,772
M2: Flat Roof Insulation	2.8	£87	577	2,770	1,750	£1,175	£413	14	.5	2.4	1.5	46,617
M35: Air To Air Heat Pump	11.9	£297	3,747	20,942	7,901	£4,500	£377	15	.8	4.7	1.8	110,963
M8: Secondary Glazing To 2.4	2.3	£79	452	2,281	1,674	£1,250	£545	16	.4	1.8	1.3	99,270
M25: Programmer For Heating System	.2	£11	3,402	17,407	10,516	£200	£958	18	.3	1.9	1.6	10,886
M22: Air Source Heat Pump	14.2	£444	69	388	318	£8,000	£564	18	.4	2.2	1.3	6,201
M23: Ground Source Heat Pump	19.2	£545	4,623	20,481	24,976	£13,000	£677	24	.4	1.6	1.9	10,800
M18: Full Biomass Central Heating System Inc Controls	11.3	£367	7,367	10,942	14,730	£10,000	£884	27	.7	1.1	1.5	14,979
M5: Solid Wall Insulation	9.6	£307	1,894	9,318	6,644	£9,000	£935	29	.2	1.0	.7	229,762
M10: Insulated External Doors	.9	£26	162	846	514	£908	£998	35	.2	.9	.6	397,356
M32: 5M Wind Turbine On Stand-Alone Mast	14.9	£419	1,629	9,636	3,139	£20,000	£1,343	48	.1	.5	.2	326,251
M31: 2M Diameter Wind Turbine On Roof	1.7	£50	193	1,144	373	£2,750	£1,639	55	.1	.4	.1	346,307
M29: Solar Thermal $4M^2$	2.9	£88	444	2,205	1,580	£5,000	£1,712	57	.1	.4	.3	246,667
M7: Double Glazing To 1.8	2.4	£84	478	2,399	1,718	£4,900	£2,002	58	.1	.5	.4	103,520
M30: Pv 2Kwp	6.4	£181	710	4,197	1,367	£11,500	£1,808	63	.1	.4	.1	255,674
M9: Triple Glazing To 1.4	2.0	£61	374	1,924	1,238	£7,500	£3,814	123	.0	.3	.2	314,738

Table A8.7: Measures included in packages for each scenario by tenure (Scenarios 1 to 4).

	Scenario 1				Scenario 2				Scenario 3				Scenario 4			
	All dwellings to reach Band F				All dwellings to reach Band E				All dwellings to reach Band D				ALL dwellings to improve 1 band			
	OO		PRS		OO		PRS		OO		PRS		OO		PRS	
	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total
Base (Total dwellings improved)		17,776		11,900		128,680		42,028		322,838		77,710		322,838		77,710
M1: Loft Insulation, Including Top Up	57%	10,074	70%	8,301	41%	52,174	53%	22,195	39%	125,049	41%	32,207	32%	104,870	37%	28,510
M2: Flat Roof Insulation	0%	0	0%	0	1%	1,010	1%	570	2%	6,231	1%	1,129	1%	3,445	1%	612
M3: Room In The Roof Insulation	0%	0	0%	0	8%	10,602	15%	6,212	18%	56,965	18%	14,110	5%	15,770	4%	2,952
M4: Cavity Wall Insulation	11%	2,009	5%	641	15%	19,860	11%	4,751	26%	82,685	26%	20,565	17%	56,317	10%	7,533
M5: Solid Wall Insulation	0%	0	0%	0	1%	910	1%	271	7%	21,198	11%	8,362	1%	3,076	1%	462
M6: Floor Insulation	8%	1,410	2%	222	6%	7,346	5%	1,917	21%	67,205	27%	20,601	9%	29,303	7%	5,679
M7: Double Glazing To 1.8	0%	0	0%	0	0%	0	0%	0	1%	2,113	1%	588	0%	0	0%	0
M8: Secondary Glazing To 2.4	0%	0	0%	0	0%	208	1%	230	1%	3,473	4%	3,031	1%	1,630	1%	618
M10: Insulated External Doors	0%	0	0%	0	1%	1,334	1%	270	3%	8,978	3%	2,218	2%	5,129	2%	1,387
M11: Hot Water Tank Jacket 80Mm	15%	2,639	17%	2,012	14%	17,474	10%	4,309	22%	70,013	23%	18,166	16%	51,520	14%	10,887
M12: Draughtproof Windows And	0%	0	0%	0	4%	5,575	5%	1,918	5%	15,660	6%	4,614	3%	9,864	5%	3,754
M13: Baffle / Damper To Open Fire	0%	0	0%	0	3%	3,442	5%	1,970	6%	19,872	3%	2,343	5%	15,986	4%	3,183
M14: Replace With Conden Boiler	0%	0	0%	0	3%	3,925	1%	595	8%	24,494	2%	1,434	4%	11,867	1%	783
M15: Replace Oil/LPG Boiler to 90%	4%	769	2%	234	6%	8,306	4%	1,740	7%	21,912	9%	6,654	2%	8,004	2%	1,726
M16: Full Gas CH System Inc Controls	0%	0	0%	0	0%	0	0%	0	0%	1,509	0%	195	0%	0	0%	0
M17: Full Oil/LPG CH System Inc	0%	39	0%	37	1%	1,285	1%	517	1%	3,015	3%	2,297	0%	742	0%	37
M18: Full Biomass CH System Inc Con	0%	0	0%	0	0%	0	0%	41	0%	0	0%	41	0%	0	0%	0
M19: Fan Elec Storage H With ACC	11%	1,905	8%	973	8%	10,769	14%	5,772	4%	13,178	8%	6,033	3%	9,493	8%	5,849
M20: Quantum Storage Heaters	0%	0	0%	0	3%	3,881	9%	3,799	8%	26,082	17%	13,209	3%	8,860	6%	4,824
M24: Room Thermostat	18%	3,135	11%	1,322	7%	9,532	8%	3,466	15%	49,314	12%	9,049	11%	36,919	6%	4,833
M26: TRVs	5%	943	2%	181	1%	1,713	3%	1,268	6%	20,905	5%	3,959	5%	15,216	4%	3,154
M27: Full Controls Package	0%	0	0%	0	2%	3,214	1%	312	1%	3,756	1%	1,061	1%	2,681	0%	312

	Scenario 1				Scenario 2				Scenario 3				Scenario 4			
	All dwellings to reach Band F				All dwellings to reach Band E				All dwellings to reach Band D				ALL dwellings to improve 1 band			
	OO		PRS		OO		PRS		OO		PRS		OO		PRS	
	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total
M28: Auto Charge Control	0%	0	0%	0	1%	1,490	1%	534	1%	3,975	1%	963	2%	5,465	1%	982
M29: Solar Thermal $4m^2$	0%	0	0%	0	0%	0	0%	0	1%	3,123	0%	222	0%	0	0%	0
M31: 2m Wind Turbine on Roof	0%	0	0%	0	0%	0	0%	0	0%	495	1%	791	0%	495	1%	791
M33: Low Energy Lighting 100%	4%	718	2%	231	17%	21,770	9%	3,726	35%	111,908	31%	23,754	27%	86,946	18%	14,364
M34: Cylinder Stat For HW Cylinder	4%	708	0%	0	2%	2,791	0%	0	4%	14,257	4%	3,032	3%	9,418	1%	632
M36: Replace Sec Heating	11%	2,014	4%	523	12%	15,439	15%	6,262	17%	53,911	21%	16,362	10%	31,470	9%	6,742
M38: Switch Electricity Tariff	1%	185	4%	426	1%	1,668	3%	1,210	3%	9,736	5%	3,664	3%	11,087	6%	4,951

Table A8.8: Measures included in package for each scenario by base EPC band (Scenarios 2 to 4).

	Scenario 2				Scenario 3						Scenario 4					
	All dwellings to reach Band				All dwellings to reach Band D						ALL EFG dwellings to improve one band					
	From G		From F		From G		From F		From E		G to F		F to E		E to D	
	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total
Base (Total dwellings improved)		29,676		141,032		29,676		141,032		229,840		29,676		141,032		229,840
M1: Loft Insulation, Including Top Up	63%	18,560	40%	55,808	67%	19,920	55%	78,139	26%	59,196	62%	18,375	40%	55,808	40%	90,951
M2: Flat Roof Insulation	0%	0	1%	1,579	0%	0	3%	4,882	1%	2,478	0%	0	1%	1,579	1%	2,574
M3: Room In The Roof Insulation	33%	9,702	5%	7,112	32%	9,535	35%	49,930	5%	11,610	0%	0	5%	7,112	5%	11,591
M4: Cavity Wall Insulation	14%	4,142	15%	20,469	35%	10,531	37%	51,988	18%	40,731	9%	2,649	15%	20,469	15%	33,359
M5: Solid Wall Insulation	4%	1,181	0%	0	35%	10,275	11%	15,748	2%	3,538	0%	0	0%	0	0%	0
M6: Floor Insulation	9%	2,646	5%	6,617	63%	18,722	30%	42,350	12%	26,734	5%	1,632	5%	6,617	5%	10,783
M7: Double Glazing To 1.8	0%	0	0%	0	9%	2,701	0%	0	0%	0	0%	0	0%	0	0%	0
M8: Secondary Glazing To 2.4	1%	208	0%	230	8%	2,343	2%	2,142	1%	2,018	0%	0	0%	230	0%	375
M10: Insulated External Doors	0%	0	1%	1,604	8%	2,476	3%	3,808	2%	4,912	0%	0	1%	1,604	1%	2,614
M11: Hot Water Tank Jacket 80Mm	22%	6,433	11%	15,351	29%	8,495	26%	37,280	18%	42,404	16%	4,651	11%	15,351	11%	25,017
M12: Draughtproof Winds & Doors	7%	1,941	4%	5,551	4%	1,194	8%	11,014	4%	8,067	0%	0	4%	5,551	4%	9,047
M13: Baffle / Damper To Open Fire	0%	0	4%	5,412	4%	1,068	5%	7,390	6%	13,757	0%	0	4%	5,412	4%	8,820

	Scenario 2				Scenario 3						Scenario 4					
	All dwellings to reach Band				All dwellings to reach Band D						ALL EFG dwellings to improve one band					
	From G		From F		From G		From F		From E		G to F		F to E		E to D	
	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total
M14: Replace with Cond Boiler 88%	3%	872	3%	3,648	3%	872	11%	16,053	4%	9,003	0%	0	3%	3,648	3%	5,944
M15: Replace Oil/LPG Boiler to 90%	18%	5,424	3%	4,622	21%	6,124	13%	18,336	2%	4,106	3%	1,002	3%	4,622	3%	7,532
M16: Full Gas CH System Inc Controls	0%	0	0%	0	2%	702	1%	1,002	0%	0	0%	0	0%	0	0%	0
M17: Full Oil/LPG CH System Inc	4%	1,099	0%	704	9%	2,784	2%	2,528	0%	0	0%	76	0%	704	0%	1,147
M18: Full Biomass CH System Inc Con	0%	41	0%	0	0%	41	0%	0	0%	0	0%	0	0%	0	0%	0
M19: Fan Elec Storage H With ACC	34%	10,105	5%	6,436	6%	1,817	8%	11,365	3%	6,029	10%	2,878	5%	6,436	5%	10,489
M20: Quantum Storage Heaters	10%	2,850	3%	4,830	41%	12,069	13%	18,368	4%	8,854	0%	0	3%	4,830	3%	7,871
M24: Room Thermostat	15%	4,373	6%	8,626	19%	5,652	17%	24,041	12%	28,670	15%	4,457	6%	8,626	6%	14,057
M26: TRVs	2%	539	2%	2,442	3%	931	6%	9,128	6%	14,805	4%	1,124	2%	2,442	2%	3,979
M27: Full Controls Package	2%	532	2%	2,994	9%	2,575	2%	2,241	0%	0	0%	0	2%	2,994	2%	4,879
M28: Auto Charge Control	0%	0	1%	2,024	0%	0	0%	515	2%	4,424	0%	0	1%	2,024	1%	3,298
M29: Solar Thermal $4m^2$	0%	0	0%	0	9%	2,612	1%	733	0%	0	0%	0	0%	0	0%	0
M31: 2m Wind Turbine on Roof	0%	0	0%	0	0%	0	0%	0	1%	1,287	0%	0	0%	0	0%	0
M33: Low Energy Lighting 100%	7%	2,181	17%	23,315	49%	14,508	31%	44,108	34%	77,046	3%	949	17%	23,315	17%	37,996
M34: Cylinder Stat For HW Cylinder	3%	827	1%	1,964	4%	1,058	6%	8,851	3%	7,379	2%	708	1%	1,964	1%	3,200
M36: Replace Sec Heating	17%	5,001	12%	16,700	27%	8,133	31%	43,165	8%	18,975	9%	2,537	12%	16,700	12%	27,215
M38: Switch Electricity Tariff	0%	0	2%	2,878	0%	0	1%	851	5%	12,549	2%	611	2%	2,878	2%	4,690

Table A8.9: Measures included in packages for each scenario by rurality (Scenarios 1 to 4).

	Scenario 1				Scenario 2				Scenario 3				Scenario 4			
	All dwellings to reach Band F				All dwellings to reach Band E				All dwellings to reach Band D				ALL dwellings to improve one band			
	Rural		Urban		Rural		Urban		Rural		Urban		Rural		Urban	
	%age	Total	%age	Total	%age	Total	%age	Total	%age	Total	%age	Total	%age	Total	%age	Total
Base (Total dwellings improved)		19,910		9,767		100,909		69,799		167,057		233,491		167,057		233,491
M1: Loft Insulation, Including Top Up	64%	12,703	58%	5,672	40%	40,600	48%	33,769	43%	72,050	36%	85,206	37%	61,150	31%	72,230
M2: Flat Roof Insulation	0%	0	0%	0	0%	350	2%	1,229	2%	3,750	2%	3,610	1%	1,553	1%	2,504
M3: Room In The Roof Insulation	0%	0	0%	0	15%	15,240	2%	1,574	28%	46,739	10%	24,337	6%	9,988	4%	8,734

	Scenario 1				Scenario 2				Scenario 3				Scenario 4			
	All dwellings to reach Band F				All dwellings to reach Band E				All dwellings to reach Band D				ALL dwellings to improve one band			
	Rural		Urban		Rural		Urban		Rural		Urban		Rural		Urban	
	%age	Total	%age	Total	%age	Total	%age	Total	%age	Total	%age	Total	%age	Total	%age	Total
M4: Cavity Wall Insulation	9%	1,756	9%	893	16%	15,844	13%	8,767	28%	46,981	24%	56,269	14%	23,026	17%	40,823
M5: Solid Wall Insulation	0%	0	0%	0	1%	1,181	0%	0	14%	23,160	3%	6,400	1%	2,433	0%	1,105
M6: Floor Insulation	8%	1,632	0%	0	9%	8,761	1%	502	40%	66,675	9%	21,131	15%	24,523	4%	10,460
M7: Double Glazing To 1.8	0%	0	0%	0	0%	0	0%	0	0%	356	1%	2,345	0%	0	0%	0
M8: Secondary Glazing To 2.4	0%	0	0%	0	0%	399	0%	40	2%	3,922	1%	2,582	0%	230	1%	2,018
M10: Insulated External Doors	0%	0	0%	0	2%	1,604	0%	0	5%	7,930	1%	3,265	2%	3,475	1%	3,041
M11: Hot Water Tank Jacket 80Mm	13%	2,626	21%	2,026	11%	11,142	15%	10,642	22%	36,192	22%	51,987	13%	21,385	18%	41,022
M12: Draughtproof Windows And Doors	0%	0	0%	0	4%	4,200	5%	3,292	6%	9,784	4%	10,490	2%	3,550	4%	10,068
M13: Baffle / Damper To Open Fire	0%	0	0%	0	5%	5,049	1%	363	5%	8,755	6%	13,459	5%	7,871	5%	11,298
M14: Replace With Conden Boiler 88%	0%	0	0%	0	1%	1,406	4%	3,113	3%	5,051	9%	20,877	1%	2,068	5%	10,582
M15: Replace Oil/LPG Boiler to 90%	5%	1,002	0%	0	9%	9,369	1%	678	16%	26,364	1%	2,203	5%	8,942	0%	788
M16: Full Gas CH System Inc Controls	0%	0	0%	0	0%	0	0%	0	0%	507	1%	1,197	0%	0	0%	0
M17: Full Oil/LPG CH System Inc	0%	76	0%	0	2%	1,613	0%	190	3%	4,768	0%	544	0%	590	0%	190
M18: Full Biomass CH System Inc Con	0%	0	0%	0	0%	41	0%	0	0%	41	0%	0	0%	0	0%	0
M19: Fan Elec Storage H With ACC	1%	187	28%	2,690	6%	6,510	14%	10,031	3%	5,417	6%	13,794	2%	4,076	5%	11,266
M20: Quantum Storage Heaters	0%	0	0%	0	5%	5,250	3%	2,430	13%	20,907	8%	18,384	4%	6,472	3%	7,211
M24: Room Thermostat	22%	4,423	0%	34	10%	10,258	4%	2,740	21%	35,432	10%	22,931	12%	20,211	9%	21,542
M26: TRVs	1%	217	9%	907	1%	1,394	2%	1,586	6%	9,384	7%	15,480	4%	6,295	5%	12,075
M27: Full Controls Package	0%	0	0%	0	3%	2,994	1%	532	2%	3,603	1%	1,214	2%	2,994	0%	0
M28: Auto Charge Control	0%	0	0%	0	0%	173	3%	1,851	1%	2,421	1%	2,518	1%	2,078	2%	4,369
M29: Solar Thermal $4m^2$	0%	0	0%	0	0%	0	0%	0	2%	2,971	0%	375	0%	0	0%	0
M31: 2m Wind Turbine on Roof	0%	0	0%	0	0%	0	0%	0	0%	0	1%	1,287	0%	0	1%	1,287
M33: Low Energy Lighting 100%	1%	199	8%	750	15%	15,580	14%	9,916	30%	50,940	36%	84,722	20%	33,528	29%	67,782
M34: Cylinder Stat For HW Cylinder	4%	708	0%	0	2%	1,602	2%	1,189	8%	12,807	2%	4,482	4%	6,086	2%	3,964
M36: Replace Sec Heating	13%	2,537	0%	0	17%	17,551	6%	4,149	29%	48,391	9%	21,882	16%	27,042	5%	11,170
M38: Switch Electricity Tariff	1%	185	4%	426	2%	1,841	1%	1,037	3%	5,147	4%	8,253	4%	6,571	4%	9,467

Additional tables on scenarios by turnover rates, tenure, and rurality.

Table A8.10: Progress towards Scenario 1 - all dwellings to reach F – based on estimated turnover rates.

	After Year 1	After Year 2	After Year 3	After Year 5	After Year 10	After Year 20	After Year 30	All Dwellings
Number of dwellings improved	4,520	6,476	8,104	10,550	14,792	21,554	25,431	29,676
%age carried out	15%	22%	27%	36%	50%	73%	86%	100%
Number carried out among OO	569	907	1,546	2,791	5,582	10,772	14,114	17,776
%age carried out among OO	3%	5%	9%	16%	31%	61%	79%	100%
Number carried out among PRS	3,951	5,569	6,557	7,759	9,211	10,782	11,317	11,900
%age carried out among PRS	33%	47%	55%	65%	77%	91%	95%	100%
Number carried out in rural areas	2,849	4,089	5,153	6,775	9,643	14,277	16,966	19,910
%age carried out in rural areas	14%	21%	26%	34%	48%	72%	85%	100%
Number carried out in urban areas	1,671	2,387	2,951	3,775	5,150	7,277	8,466	9,767
%age carried out in urban areas	17%	24%	30%	39%	53%	75%	87%	100%
Overall capital cost	£2.4 m	£3.4 m	£4.4 m	£5.9 m	£8.6 m	£13.1 m	£15.7 m	£18.6 m
Overall reduction in annual fuel costs	£2.4 m	£3.5 m	£4.4 m	£5.7 m	£8.0 m	£11.7 m	£13.8 m	£16.1 m
Overall reduction in annual CO_{2e} (thousand tons)	9.8 k tons	14. k tons	17.4 k tons	22.6 k tons	31.6 k tons	45.7 k tons	53.8 k tons	62.7 k tons
Overall reduction in Delivered Energy (kWh pa)	31.64 m	45.31 m	56.6 m	73.5 m	102.65 m	148.93 m	175.38 m	204.33 m
Overall reduction in Primary Energy (kWh pa)	48.14 m	68.9 m	85.93 m	111.31 m	154.89 m	223.8 m	263.06 m	306.04 m
Average SAP point increase among improved dwellings	14.7	14.7	14.6	14.4	14.2	13.9	13.8	13.7

Table A8.11: Progress towards Scenario 2 - all dwellings to reach E - based on estimated turnover rates.

	After Year 1	After Year 2	After Year 3	After Year 5	After Year 10	After Year 20	After Year 30	All Dwellings
Number of dwellings improved	18,071	26,232	34,353	47,605	72,935	116,057	142,140	170,708
%age carried out	11%	15%	20%	28%	43%	68%	83%	100%
Number carried out among OO	4,118	6,563	11,195	20,203	40,405	77,980	102,172	128,680
%age carried out among OO	3%	5%	9%	16%	31%	61%	79%	100%
Number carried out among PRS	13,953	19,669	23,157	27,402	32,530	38,077	39,969	42,028
%age carried out among PRS	33%	47%	55%	65%	77%	91%	95%	100%
Number carried out in rural areas	11,171	16,186	21,063	28,948	43,864	69,093	84,278	100,909
%age carried out in rural areas	11%	16%	21%	29%	43%	68%	84%	100%
Number carried out in urban areas	6,900	10,046	13,289	18,657	29,071	46,964	57,862	69,799
%age carried out in urban areas	10%	14%	19%	27%	42%	67%	83%	100%
Number carried out in EPC Band G	4,520	6,476	8,104	10,550	14,792	21,554	25,431	29,676
%age carried out in EPC Band G	15%	22%	27%	36%	50%	73%	86%	100%
Number carried out in EPC Band F	13,551	19,756	26,249	37,055	58,143	94,503	116,709	141,032
%age carried out in EPC Band F	10%	14%	19%	26%	41%	67%	83%	100%
Overall capital cost	£23.8 m	£34.4 m	£44.7 m	£61.2 m	£92.2 m	£144.5 m	£175.9 m	£210.2 m
Overall reduction in annual fuel costs	£9.2 m	£13.3 m	£17.2 m	£23.4 m	£35.0 m	£54.5 m	£66.2 m	£79.0 m
Overall reduction in annual CO_{2e} (thousand tons)	41.9 k tons	60.5 k tons	78.3 k tons	106.7 k tons	160. k tons	249.5 k tons	303. k tons	361.7 k tons
Overall reduction in Delivered Energy (kWh pa)	142 m	206 m	267 m	367 m	555 m	873 m	1064 m	1273 m
Overall reduction in Primary Energy (kWh pa)	197 m	284 m	368 m	501 m	749 m	1166 m	1416 m	1689 m
Average SAP point increase among improved dwellings	15.7	15.6	15.3	14.9	14.3	13.8	13.6	13.4

Table A8.12: Progress towards Scenario 3 - all dwellings to reach D - based on estimated turnover rates.

	After Year 1	After Year 2	After Year 3	After Year 5	After Year 10	After Year 20	After Year 30	All Dwellings
Number of dwellings improved	39,227	57,205	75,908	107,699	171,407	278,445	344,620	400,548
%age carried out	10%	14%	19%	27%	43%	70%	86%	100%
Number carried out among OO	11,107	18,018	29,058	52,821	107,584	205,542	269,148	322,838
%age carried out among OO	3%	6%	9%	16%	33%	64%	83%	100%
Number carried out among PRS	28,119	39,187	46,850	54,877	63,823	72,903	75,472	77,710
%age carried out among PRS	36%	50%	60%	71%	82%	94%	97%	100%
Number carried out in rural areas	17,379	25,262	33,212	46,441	72,379	115,934	142,597	167,057
%age carried out in rural areas	10%	15%	20%	28%	43%	69%	85%	100%
Number carried out in urban areas	21,847	31,944	42,696	61,257	99,028	162,511	202,023	233,491
%age carried out in urban areas	9%	14%	18%	26%	42%	70%	87%	100%
Number carried out in EPC Band G	4,520	6,476	8,104	10,550	14,792	21,554	25,431	29,676
%age carried out in EPC Band G	15%	22%	27%	36%	50%	73%	86%	100%
Number carried out in EPC Band F	13,551	19,756	26,249	37,055	58,143	94,503	116,709	141,032
%age carried out in EPC Band F	10%	14%	19%	26%	41%	67%	83%	100%
Number carried out in EPC Band E	21,155	30,973	41,555	60,094	98,472	162,388	202,480	229,840
%age carried out in EPC Band E	9%	13%	18%	26%	43%	71%	88%	100%
Overall capital cost	£113 m	£164 m	£215 m	£299 m	£462 m	£737 m	£905 m	£1070 m
Overall reduction in annual fuel costs	£19.7 m	£28.6 m	£37.7 m	£52.8 m	£82.4 m	£132.4 m	£163.0 m	£193.0 m
Overall reduction in annual CO_{2e} (thousand tons)	103 k tons	150 k tons	199 k tons	281 k tons	442 k tons	715 k tons	883 k tons	1046 k tons
Overall reduction in Delivered Energy (kWh pa)	340 m	497 m	661 m	939 m	1490 m	2430 m	3008 m	3569 m
Overall reduction in Primary Energy (kWh pa)	497 m	725 m	958 m	1351 m	2127 m	3444 m	4251 m	5030 m
Average SAP point increase among improved dwellings	18.1	18.0	17.7	17.3	16.8	16.4	16.2	16.4

Table A8.13: Progress towards Scenario 4 - all EFG dwellings to move up one band - based on estimated turnover.

	After Year 1	After Year 2	After Year 3	After Year 5	After Year 10	After Year 20	After Year 30	All Dwellings
Number of dwellings improved	39,227	57,205	75,908	107,699	171,407	278,445	344,620	400,548
%age carried out	10%	14%	19%	27%	43%	70%	86%	100%
Number carried out among OO	11,107	18,018	29,058	52,821	107,584	205,542	269,148	322,838
%age carried out among OO	3%	6%	9%	16%	33%	64%	83%	100%
Number carried out among PRS	28,119	39,187	46,850	54,877	63,823	72,903	75,472	77,710
%age carried out among PRS	36%	50%	60%	71%	82%	94%	97%	100%
Number carried out in rural areas	17,379	25,262	33,212	46,441	72,379	115,934	142,597	167,057
%age carried out in rural areas	10%	15%	20%	28%	43%	69%	85%	100%
Number carried out in urban areas	21,847	31,944	42,696	61,257	99,028	162,511	202,023	233,491
%age carried out in urban areas	9%	14%	18%	26%	42%	70%	87%	100%
Number carried out in EPC Band G	4,520	6,476	8,104	10,550	14,792	21,554	25,431	29,676
%age carried out in EPC Band G	15%	22%	27%	36%	50%	73%	86%	100%
Number carried out in EPC Band F	13,551	19,756	26,249	37,055	58,143	94,503	116,709	141,032
%age carried out in EPC Band F	10%	14%	19%	26%	41%	67%	83%	100%
Number carried out in EPC Band E	21,155	30,973	41,555	60,094	98,472	162,388	202,480	229,840
%age carried out in EPC Band E	9%	13%	18%	26%	43%	71%	88%	100%
Overall capital cost	£36 m	£53 m	£70 m	£101 m	£163 m	£269 m	£334 m	£388 m
Overall reduction in annual fuel costs	£11.1 m	£16.2 m	£21.4 m	£30.2 m	£47.7 m	£77.1 m	£95.3 m	£111.6 m
Overall reduction in annual CO_{2e} (thousand tons)	58 k tons	85 k tons	112 k tons	160 k tons	256 k tons	417 k tons	517 k tons	606 k tons
Overall reduction in Delivered Energy (kWh pa)	186 m	272 m	364 m	524 m	849 m	1400 m	1742 m	2044 m
Overall reduction in Primary Energy (kWh pa)	283 m	414 m	550 m	784 m	1254 m	2046 m	2537 m	2968 m
Average SAP point increase among improved dwellings	10.1	10.0	9.9	9.8	9.6	9.4	9.4	9.4

Table A8.14: Scenarios by rurality

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	All dwellings to reach Band F		All dwellings to reach Band E		All dwellings to reach Band D		ALL EFG dwellings to improve one band	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Number of dwellings improved	19,910	9,767	100,909	69,799	167,057	233,491	167,057	233,491
Mean SAP base	12.9	11.2	27.8	29.3	35.4	42.3	35.4	42.3
Mean SAP increase	11.4	18.5	13.2	13.8	20.2	13.8	9.5	9.3
Mean EI score base	24.3	23.6	24.3	24.9	28.9	34.9	28.9	34.9
Mean EI score increase	7.3	8.3	7.5	7.7	14.5	10.1	6.9	6.9
Mean capital cost of improvements	£673	£532	£1,523	£811	£4,092	£1,656	£1,166	£828
Overall capital cost of improvements	£13.4 m	£5.2 m	£153.7 m	£56.6 m	£683.6 m	£386.7 m	£194.8 m	£193.3 m
Banded capital cost: %age (n) £0-£200	17% (3,330)	6% (607)	13% (12,678)	12% (8,663)	8% (13,397)	23% (54,681)	18% (29,405)	27% (63,951)
Banded capital cost: %age (n) £201-£500	51% (10,194)	53% (5,202)	28% (28,655)	45% (31,314)	6% (9,335)	19% (43,354)	29% (47,990)	31% (73,343)
Banded capital cost: %age (n) £501-£1,000	15% (2,893)	32% (3,107)	14% (13,875)	16% (11,227)	9% (14,949)	7% (15,238)	18% (30,285)	11% (26,802)
Banded capital cost: %age (n) £1,001-£2,000	12% (2,415)	9% (851)	10% (10,414)	14% (10,103)	10% (17,321)	19% (45,404)	16% (26,132)	17% (39,914)
Banded capital cost: %age (n) £2,001-£5,000	5% (1,002)	0% (-)	32% (32,653)	12% (8,492)	42% (69,452)	27% (63,549)	18% (30,063)	12% (28,111)
Banded capital cost: %age (n) £5,001-£10,000	0% (76)	0% (-)	2% (2,160)	0% (-)	13% (21,861)	3% (7,252)	2% (3,183)	1% (1,369)
Banded capital cost: %age (n) >£10,000	0% (-)	0% (-)	0% (473)	0% (-)	12% (20,743)	2% (4,013)	0% (-)	0% (-)
Mean fuel cost pre improvement	£2,653	£2,077	£2,170	£1,907	£1,896	£1,461	£1,896	£1,461
Mean reduction in fuel costs	£525	£578	£498	£412	£644	£367	£326	£246
Overall fuel cost pre improvement	£52.8m	£20.3m	£218.9 m	£133.1 m	£316.7 m	£341.2 m	£316.7 m	£341.2m
Overall reduction in fuel costs	£10.5 m	£5.6 m	£50.2 m	£28.7 m	£107.6 m	£85.4 m	£54.5 m	£57.1 m
Mean CO_{2e} consumed pre improvement	12,322 kg	8,904 kg	12,166 kg	10,792 kg	10,815 kg	8,248 kg	10,815 kg	8,248 kg
Mean reduction in CO_{2e} consumed	2,366 kg	1,597 kg	2,302 kg	1,854 kg	3,488 kg	1,992 kg	1,770 kg	1,333 kg
Overall CO_{2e} consumed pre improvement	245 k tons	87 k tons	1,228 k tons	753 k tons	1,807 k tons	1,926 k tons	1,807 k tons	1,926 k tons
Overall reduction in CO_{2e}	47.1 k tons	15.6 k tons	232.3 k tons	129.4 k tons	582.7 k tons	463.4 k tons	295.7 k tons	310.1 k tons

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	All dwellings to reach Band F		All dwellings to reach Band E		All dwellings to reach Band D		ALL EFG dwellings to improve one band	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Mean Primary Energy consumed pre improvement	58,127	50,737	54,112	59,016	48,797	45,259	48,797	45,259
Mean reduction in PE	11,313	8,274	9,821	10,000	15,165	10,729	7,792	7,159
Overall PE consumed before package	1,157 m	496 m	5,460 m	4,119 m	8,152 m	10,567 m	8,152 m	10,567 m
Overall reduction in PE	225 m	81 m	991 m	698 m	2,533 m	2,497 m	1,302 m	1,666 m
Mean Delivered Energy consumed pre improvement	42,919	23,256	38,170	36,610	33,315	29,523	33,315	29,523
Mean reduction in DE	8,237	4,130	8,361	6,157	11,462	7,107	5,695	4,697
Overall DE consumed before package	854 m	227 m	3,852 m	2,555 m	5,566 m	6,893 m	5,566 m	6,893 m
Overall reduction in DE	164 m	40 m	844 m	430 m	1,915 m	1,654 m	951 m	1,093 m
Median payback period	1.11	.98	2.97	1.61	5.06	3.24	2.59	2.46
Mean payback period	1.28	0.92	3.06	1.97	6.36	4.51	3.58	3.37
Mean capital cost per SAP point increase	£59	£29	£115	£59	£203	£120	£122	£89

Table A8.15: Scenarios by tenure (Owner-occupied compared to Private Rented Sector)

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	All dwellings to reach Band F		All dwellings to reach Band E		All dwellings to reach Band D		ALL EFG dwellings to improve one band	
	OO	PRS	OO	PRS	OO	PRS	OO	PRS
Number of dwellings improved	17,776	11,900	128,680	42,028	322,838	77,710	322,838	77,710
Mean SAP score pre improvement	12.2	12.4	29.4	25.6	40.3	35.8	40.3	35.8
Mean SAP score increase	12.9	15.0	12.4	16.7	15.5	20.2	9.1	10.6
Mean EI score pre improvements	24.0	24.3	25.2	22.7	32.8	30.8	32.8	30.8
Mean EI score increase	6.7	9.1	7.1	9.1	11.6	13.2	6.8	7.0
Mean capital cost of	£710	£502	£1,192	£1,353	£2,538	£3,230	£992	£873
Overall capital cost of improvements	£12.6 m	£6.0 m	£153.4 m	£56.9 m	£819.2 m	£251.0 m	£320.2 m	£67.9 m
Banded capital cost: %age (n) £0-£200	16% (2,931)	8% (1,005)	14% (17,815)	8% (3,526)	17% (54,537)	17% (13,541)	23% (75,284)	23% (18,072)
Banded capital cost: %age (n) £201-£500	39% (6,908)	71% (8,488)	35% (45,234)	35% (14,736)	14% (44,104)	11% (8,585)	29% (92,318)	37% (29,015)
Banded capital cost: %age (n) £501-£1,000	24% (4,312)	14% (1,688)	17% (21,469)	9% (3,633)	7% (24,195)	8% (5,993)	15% (47,379)	12% (9,708)
Banded capital cost: %age (n) £1,001-£2,000	16% (2,817)	4% (449)	10% (12,548)	19% (7,969)	16% (52,447)	13% (10,278)	17% (55,331)	14% (10,715)
Banded capital cost: %age (n) £2,001-£5,000	4% (769)	2% (234)	23% (29,592)	27% (11,553)	34% (109,833)	30% (23,168)	15% (48,794)	12% (9,380)
Banded capital cost: %age (n) £5,001-£10,000	0% (39)	0% (37)	1% (1,820)	1% (340)	6% (20,592)	11% (8,521)	1% (3,733)	1% (819)
Banded capital cost: %age (n) >£10,000	0% (-)	0% (-)	0% (202)	1% (271)	5% (17,131)	10% (7,625)	0% (-)	0% (-)
Mean fuel cost pre	£2,535	£2,357	£2,097	£1,957	£1,656	£1,587	£1,656	£1,587
Mean reduction in fuel costs	£547	£535	£442	£527	£466	£554	£274	£299
Overall fuel cost pre improvement	£45.1 m	£28.0 m	£269.8 m	£82.2 m	£534.5 m	£123.3 m	£534.5 m	£123.3 m
Overall reduction in fuel costs	£9.7 m	£6.4 m	£56.8 m	£22.2 m	£149.9 m	£43.0 m	£88.4 m	£23.2 m
Mean CO_{2e} consumed pre improvement	11,434 kg	10,843 kg	11,807 kg	10,983 kg	9,429 kg	8,861 kg	9,429 kg	8,861 kg
Mean reduction in CO_{2e} consumed	2,075 kg	2,169 kg	2,027 kg	2,401 kg	2,560 kg	2,852 kg	1,516 kg	1,513 kg
Overall CO_{2e} consumed pre improvement	203 k tons	129 k tons	1,519 k tons	462 k tons	3,044 k tons	689 k tons	3,044 k tons	689 k tons
Overall reduction in CO_{2e}	36.9 k tons	25.8 k tons	260.8 k tons	100.9 k tons	824.5 k tons	221.6 k tons	488.2 k tons	117.6 k tons

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	All dwellings to reach Band F		All dwellings to reach Band E		All dwellings to reach Band D		ALL EFG dwellings to improve one band	
	OO	PRS	OO	PRS	OO	PRS	OO	PRS
Mean Primary Energy	57,353	53,218	56,874	53,798	47,266	44,525	47,266	44,525
Mean reduction in PE	10,026	10,740	9,430	11,314	12,305	13,734	7,428	7,407
Overall PE consumed before package	1,019 m	633 m	7,319 m	2,261 m	15,259 m	3,460 m	15,259 m	3,460 m
Overall reduction in PE	178 m	128 m	1,214 m	476 m	3,963 m	1,067 m	2,392 m	576 m
Mean Delivered Energy	36,863	35,827	38,807	33,630	31,991	27,422	31,991	27,422
Mean reduction in DE	6,788	7,031	7,275	8,024	8,845	9,265	5,209	4,717
Overall DE consumed before package	655 m	426 m	4,994 m	1,413 m	10,328 m	2,131 m	10,328 m	2,131 m
Overall reduction in DE	121 m	84 m	936 m	337 m	2,849 m	720 m	1,678 m	367 m
Median payback period	1.06	.74	2.21	2.39	3.75	3.75	2.56	1.85
Mean payback period	1.30	0.94	2.70	2.57	5.45	5.83	3.61	2.92
Mean capital cost per SAP point increase	£55	£34	£96	£81	£164	£160	£109	£82

Table A8.16: Scenario 2 by EPC band pre-improvements

	Scenario 2 All dwellings to reach Band E		
	Dwellings in EPC band G	Dwellings in EPC band F	All dwellings
Number of dwellings improved	29,676	141,032	170,708
Mean SAP score pre improvement	12.3	31.8	28.5
Mean SAP score increase	29.5	10.0	13.4
Mean EI score pre improvements	24.1	24.7	24.6
Mean EI score increase	11.5	6.7	7.5
Mean capital cost of improvements	£2,863	£888	£1,232
Overall capital cost of improvements	£85.0 m	£125.3 m	£210.2 m
Banded capital cost: %age (n) £0-£200	0% (-)	15% (21,341)	13% (21,341)
Banded capital cost: %age (n) £201-£500	3% (935)	42% (59,035)	35% (59,970)
Banded capital cost: %age (n) £501-£1,000	12% (3,611)	15% (21,491)	15% (25,102)
Banded capital cost: %age (n) £1,001-£2,000	12% (3,504)	12% (17,012)	12% (20,517)
Banded capital cost: %age (n) £2,001-£5,000	64% (18,993)	16% (22,152)	24% (41,145)
Banded capital cost: %age (n) £5,001-£10,000	7% (2,160)	0% (-)	1% (2,160)
Banded capital cost: %age (n) >£10,000	2% (473)	0% (-)	0% (473)
Mean fuel cost pre improvement	£2,464	£1,978	£2,062
Mean reduction in fuel costs (£ per annum)	£1,053	£338	£463
Overall fuel cost pre improvement	£73.1 m	£278.9 m	£352.0 m
Overall reduction in fuel costs	£31.3 m	£47.7 m	£79.0 m
Mean CO_{2e} consumed pre improvement	11,197 kg	11,690 kg	11,604 kg
Mean reduction in CO_{2e} consumed	3,317 kg	1,867 kg	2,119 kg
Overall CO_{2e} consumed pre improvement	332k tons	1,649k tons	1,981k tons
Overall reduction in CO_{2e}	98.4k tons	263k tons	362k tons
Mean Primary Energy consumed pre	55,695	56,206	56,117
Mean reduction in PE (kWh per annum)	14,956	8,829	9,894
Overall PE consumed before package	1,653 m	7,927 m	9,580 m
Overall reduction in PE	444 m	1,245 m	1,689 m
Mean Delivered Energy consumed pre	36,447	37,760	37,532
Mean reduction in DE (kWH per annum)	13,574	6,173	7,460
Overall DE consumed before package	1,082 m	5,325 m	6,407 m
Overall reduction in DE	403 m	871 m	1,273 m
Median payback period	2.72	1.99	2.32
Mean payback period	2.72	2.63	2.66
Mean capital cost per SAP point increase	£97	£88	£92

Table A8.17: Scenario 3 by EPC band before package of improvements

	Scenario 3 All dwellings to reach Band D			
	Dwellings in EPC band G	EPC band F	EPC band E	All Dwellings in EFG
Number of dwellings improved	29,676	141,032	229,840	400,548
Mean SAP score pre improvement	12.3	31.8	47.6	39.4
Mean SAP score increase	43.4	23.8	8.4	16.4
Mean EI score pre improvements	24.1	24.7	38.2	32.4
Mean EI score increase	20.3	18.5	6.9	11.9
Mean capital cost of improvements	£8,430	£4,083	£1,062	£2,672
Overall capital cost of improvements	£250.2 m	£575.9 m	£244.2 m	£1070.2 m
Banded capital cost: %age (n) £0-£200	0% (-)	0% (-)	29% (68,078)	17% (68,078)
Banded capital cost: %age (n) £201-£500	0% (-)	4% (5,787)	21% (46,902)	13% (52,689)
Banded capital cost: %age (n) £501-£1,000	0% (-)	0% (591)	13% (29,597)	8% (30,187)
Banded capital cost: %age (n) £1,001-£2,000	8% (2,472)	10% (14,485)	20% (45,768)	16% (62,725)
Banded capital cost: %age (n) £2,001-£5,000	25% (7,318)	64% (90,662)	15% (35,020)	33% (133,000)
Banded capital cost: %age (n) £5,001-£10,000	26% (7,618)	12% (17,018)	2% (4,477)	7% (29,113)
Banded capital cost: %age (n) >£10,000	41% (12,268)	9% (12,488)	0% (-)	6% (24,756)
Mean fuel cost pre improvement	£2,464	£1,978	£1,331	£1,642
Mean reduction in fuel costs (£ per annum)	£1,398	£735	£209	£483
Overall fuel cost pre improvement	£73.1 m	£278.9 m	£305.8 m	£657.8 m
Overall reduction in fuel costs	£41.5 m	£103.7 m	£47.8 m	£193.0 m
Mean CO_{2e} consumed pre improvement	11,197 kg	11,690 kg	7,622 kg	9,319 kg
Mean reduction in CO_{2e} consumed (kg per	5,036 kg	4,374 kg	1,222 kg	2,617 kg
Overall CO_{2e} consumed pre improvement	332 k tons	1,649 k tons	1,752 k tons	3,733 k tons
Overall reduction in CO_{2e}	149 k tons	617 k tons	280 k tons	1046 k tons
Mean Primary Energy consumed pre	55,695	56,206	39,765	46,734
Mean reduction in PE (kWh per annum)	25,267	20,305	6,184	12,583
Overall PE consumed before package	1,653 m	7,927 m	9,140 m	18,719 m
Overall reduction in PE	750 m	2,864 m	1,416 m	5,030 m
Mean Delivered Energy consumed pre	36,447	37,760	26,330	31,104
Mean reduction in DE (kWh per annum)	19,511	14,325	4,232	8,927
Overall DE consumed before package	1,082 m	5,325 m	6,052 m	12,459 m
Overall reduction in DE	579 m	2,020 m	969 m	3,569 m
Median payback period	6.20	4.86	3.08	3.75
Mean payback period	6.03	5.55	5.09	5.54
Mean capital cost per SAP point increase	£194	£171	£126	£163

Table A8.18: Scenario 4 by EPC band before package of improvements

	Scenario 4 All dwellings to increase one band			
	Dwellings in band G	Dwellings in band F	Dwellings in band E	All EFG Dwellings
Number of dwellings improved	29,676	141,032	229,840	400,548
Mean SAP score pre improvement	12.3	31.8	47.6	39.4
Mean SAP score increase	13.7	10.1	8.4	9.4
Mean EI score pre improvements	24.1	24.7	38.2	32.4
Mean EI score increase	7.6	6.7	6.9	6.9
Mean capital cost of improvements	£627	£888	£1,062	£969
Overall capital cost of improvements	£18.6 m	£125.3 m	£244.2 m	£388.1 m
Banded capital cost: %age (n) £0-£200	13% (3,936)	15% (21,341)	30% (68,078)	23% (93,335)
Banded capital cost: %age (n) £201-£500	52% (15,396)	42% (59,035)	20% (46,902)	30% (121,333)
Banded capital cost: %age (n) £501-£1,000	20% (6,000)	15% (21,491)	13% (29,597)	14% (57,087)
Banded capital cost: %age (n) £1,001-£2,000	11% (3,266)	12% (17,012)	20% (45,768)	16% (66,046)
Banded capital cost: %age (n) £2,001-£5,000	3% (1,002)	16% (22,152)	15% (35,020)	15% (58,174)
Banded capital cost: %age (n) £5,001-£10,000	0% (76)	0% (-)	2% (4,477)	1% (4,553)
Banded capital cost: %age (n) >£10,000	0% (-)	0% (-)	0% (-)	0% (-)
Mean fuel cost pre improvement	£2,464	£1,978	£1,331	£1,642
Mean reduction in fuel costs (£ per annum)	£542	£338	£209	£279
Overall fuel cost pre improvement	£73.1 m	£278.9 m	£305.8 m	£657.8 m
Overall reduction in fuel costs	£16.1 m	£47.7 m	£47.8 m	£111.6 m
Mean CO_{2e} consumed pre improvement	11,197 kg	11,690 kg	7,622 kg	9,319 kg
Mean reduction in CO_{2e} consumed (kg per	2,113 kg	1,867 kg	1,222 kg	1,515 kg
Overall CO_{2e} consumed pre improvement	332 k tons	1,649 k tons	1,752 k tons	3,733 k tons
Overall reduction in CO_{2e}	62.7 k tons	263.3 k tons	279.8 k tons	605.8 k tons
Mean Primary Energy consumed pre	55,695	56,206	39,765	46,734
Mean reduction in PE (kWh per annum)	10,313	8,829	6,184	7,424
Overall PE consumed before package	1,653 m	7,927 m	9,140 m	18,719 m
Overall reduction in PE	306 m	1,245 m	1,416 m	2,968 m
Mean Delivered Energy consumed pre	36,447	37,760	26,330	31,104
Mean reduction in DE (kWh per annum)	6,885	6,173	4,232	5,114
Overall DE consumed before package	1,082 m	5,325 m	6,052 m	12,459 m
Overall reduction in DE	204 m	871 m	969 m	2,044 m
Median payback period	1.06	1.99	3.08	2.48
Mean payback period	1.16	2.63	5.09	3.47
Mean capital cost per SAP point increase	£46	£88	£126	£103

15 APPENDIX 9: IMPACT OF IMPROVEMENTS ON TWO SAMPLE DWELLINGS

Improving the Energy Efficiency in the Detached Bungalow

15.1 For this detached bungalow, as seen in Chapter 4, 65 different single improvement measures or combinations of measures were assessed. The increases in the SAP score, the reductions in kg of CO_{2e} emissions, and the reductions in SAP fuel bills were plotted against the mean capital cost of the various improvements in Figures 4.2, 4.3 and 4.4 respectively in the main report. The median cost of the improvements assessed for this dwelling (i.e. £5450) and the median change in the respective SAP score (i.e. 43 SAP points), the reduction in Kg of CO_{2e} per year (i.e. 21,604 kg of CO_{2e}), the reduction in £ per year on the SAP fuel costs (i.e. £1,913) were used to define the axes in these graphs, quartering the graph into low cost - low impact, low cost – high impact, high cost – low impact, and high cost - high impact sections. The further left on the x-axis and further up the y-axis, the bigger the impact on the energy performance of the dwelling for the money spent.

SAP rating: Low cost - High impact improvements in the Detached Bungalow

15.2 In terms of the impact on the SAP rating, ten improvements comprised the low cost - high impact sector of the graph in Figure 4.2 in the main report: all involve heating improvements in combination with other improvements. Loft insulation is part of 9 of the packages (see Table A9.1). The cost of increasing the SAP rating by 1 point ranges between £59 and £109 per point amongst this group of improvement packages. Two of the improvements here do not raise the dwelling beyond the SAP Band of G; with the rest, the dwelling would achieve SAP Band F.

Table A9.1: SAP rating: Low cost - High impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	SAP increase	Cost per SAP point increase
Electric fan storage heating (auto) + new HWC + LI	19	G	2500	43	58.14
Electric wet thermal store on off peak E18 tariff + damper	20	G	4050	44	92.05
Electric fan storage heating (auto charge control) + new HWC + LI + DP	21	F	2600	45	57.78
Oil condensing combi 90.1% + LI	25	F	5350	49	109.18
Oil condensing combi 90.1% + LI + DP	26	F	5450	50	109.00
Oil condensing combi 90.1% + LI + DGA + DP doors	29	F	3900	53	73.58
Quantum storage heaters + new HWC + LI + DP	31	F	4000	55	72.73
Electric wet thermal store + damper+LI	32	F	4400	56	78.57
Electric wet thermal store + LI + DP	33	F	4550	57	79.82
Quantum storage heaters + new HWC + LI + DGA + DP doors + FI	38	F	5450	62	87.90

SAP rating: Low cost - Low impact improvements in Detached Bungalow

15.3 The low cost – low impact sector is comprised of 23 improvement options: a variety of insulation measures, new heating without any additional insulation, some renewables on their own, and some insulation combinations. The common factors are that the single measures and packages have an indicative cost of less than £5450, and they do not increase the SAP by 43 points or more.

15.4 The cost of raising the SAP score by 1 point can be extremely high within this group. The cost per SAP point increase ranges from £25 per point (i.e. loft insulation) up to £5000 per point increase (i.e. solar hot water). While the best measure here in terms of its £ per SAP point increase is loft insulation (at a cost of £2 per SAP point increase), its ultimate effect is negligible for the dwelling as it only raises the overall rating by 14 SAP points; the next best improvement (i.e. loft insulation and draughtproofing) only raise the rating by 15 SAP points (see Table A9.2).

15.5 None of these improvement options increase the SAP rating by enough points to raise it into the next SAP banding. Given its very poor SAP score starting point, none of the improvement options increase the SAP rating by enough points to result in an increase in its publically quoted SAP rating.

Table A9.2: SAP rating: Low cost - Low impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	SAP increase	Cost per SAP point increase
Fit baffle / damper on open fire (damper)	-23	G	50	1	50.00
Insulated doors (2 doors)	-23	G	1,000	1	1000.00
Solar hot water panels ($4m^2$)	-23	G	5,000	1	5000.00
Fit damper on open fire + DP	-22	G	150	2	75.00
Draught proof windows and doors (DP)	-22	G	100	2	50.00
Wind turbine on roof (2m diameter)	-22	G	2,750	2	1375.00
Floor insulation (U-value 0.25) (FI)	-20	G	1,000	4	250.00
Low-E Double Glazing (U-value 2.1) (DG)	-20	G	4,650	4	1162.50
Low-E + Argon filled Double Glazing (U-value 1.8) (DGA)	-20	G	4,650	4	1162.50
Electric wet central heating - direct electric on E10 tariff + new hot water cylinder (HWC)	-12	G	4,000	12	333.33
Electric wet central heating - direct electric on E10 tariff + new HWC + damper	-11	G	4,050	13	311.54
Loft insulation (U-value 0.13) (LI)	-10	G	350	14	25.00
LI + DP	-9	G	450	15	30.00
Electric room heater system on E10 tariff + new HWC	-8	G	2,150	16	134.38
Electric room heater system on E10 tariff + new HWC+ block chimney	-7	G	2,200	17	129.41

LI + DP + FI	-4	G	1,450	20	72.50
Electric wet central heating: CPSU on E18 tariff	4	G	4,000	28	142.86
Electric fan storage heating (auto) + panel heaters + new HWC + block chimney	6	G	2,500	30	83.33
Electric fan storage heating (auto) + solid fuel open fire + new HWC	7	G	4,050	31	130.65
Electric wet central heating: CPSU + block chimney	7	G	2,150	31	69.35
Oil condensing combi 90.1%	13	G	5,000	37	135.14
Electric wet - water storage boiler (thermal store) on off peak tariff	14	G	4,000	38	105.26
Quantum storage heaters + solid fuel open fire + new HWC	17	G	3,550	41	86.59

SAP rating: High cost - High impact improvements in Detached Bungalow

15.6 It is not that insulation does not have an impact on the energy rating of this dwelling (see Table A9.3); it has to be packaged. When enough insulation measures are packaged, or coupled with space heating or renewable technologies, significant increases in the SAP rating can be achieved. However, while all of these improvement options achieved more than a 43 point increase in the SAP rating they all cost more than the median of £5450. All the improvement options here achieved at least SAP Band F; some achieved Band E, and even Band D (see Table A9.3).

15.7 The cost per SAP point increase here has much narrower range than seen with the Low cost – Low impact measures. The cost per SAP point increase ranges between £198 per point up to £417 per SAP point.

Table A9.3: SAP rating: High cost - High impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	SAP increase	Cost per SAP point increase
Insulation package (LI + SWI + FI + DP)	22	F	13,458	46	292.57
Insulation package + DGA	28	F	18,071	52	347.52
Quantum storage heaters + new HWC+LI	29	F	10,534	53	198.75
Insulation package + DGA + Solar hw	30	F	22,267	54	412.35
Insulation package + DGA + Wind turbine on roof (2m diameter)	32	F	20,767	56	370.84
Quantum storage heaters + new HWC + LI + DGA + DP doors	34	F	7,338	58	126.52
Oil condensing combi 90.1% + LI + DGA + DP doors + FI	34	F	10,025	58	172.84
Insulation package + DGA + PVs	36	F	24,967	60	416.12
Electric wet thermal store + damper + LI + DGA + DP doors	37	F	9,284	61	152.20
Electric wet thermal store + damper + LI + DP + FI	38	F	9,521	62	153.56

Electric wet thermal store + damper + LI + DGA + DP doors + FI	41	E	10,021	65	154.17
Insulation package + DGA + ASHP + new HWC	48	E	26,067	72	362.04
Insulation package + DGA + Electric Storage Heating + new HWC	50	E	20,167	74	272.53
Insulation package + DGA + SF range 67.5% + new HWC	51	E	27,267	75	363.56
Insulation package + DGA + Electric Storage Heating + electric panel heaters + new HWC	53	E	20,417	77	265.16
Insulation package + DGA + oil condensing combi 90.1%	55	D	23,417	79	296.42
Insulation package + DGA + Ground Source Heat Pump	55	D	30,767	79	389.46
Insulation package + DGA + oil condensing range 90% + new HWC	58	D	24,167	82	294.72
Insulation package + Electric wet thermal store + damper	59	D	17,508	83	210.94
Insulation package + DGA + wood log boiler 80% + new HWC	60	D	26,637	84	317.11
Insulation package + DGA + Quantum storage heaters + new HWC	60	D	21,567	84	256.75
Insulation package + DGA + electric wet thermal store + damper	64	D	22,067	88	250.76
Insulation package + DGA + Wind turbine on mast (5m diameter)	68	D	38,017	92	413.23

SAP rating: High cost - Low impact improvements in the Detached Bungalow

15.8 Some measures are very expensive coupled with a relatively small gain in SAP. None of these improvement options raised the SAP Banding of this bungalow above its starting level of G, yet each still cost more than £5450. Nine of the improvements fell into this category (see Table 8.4).

15.9 The cost per increase of 1 SAP point ranges from between £151 and £3833, but as seen above these are not as expensive as the cost of increasing the SAP score by 1 point associated with installing a solar hot water system.

15.10 Five of the measures in this group may be eligible for payments under either the Renewable Heat Initiative (RHI) or the Feed-in-Tariffs (FiTs). Neither of these schemes provides upfront financial assistance to install the eligible improvement (so the householder still has to find this investment cost), but the two schemes do make payments to the householder for the calculated energy replaced by the technology, or for the amount of electricity generated, for a number of years into the future, e.g. 20 years under the FiTs.

Table A9.4: SAP rating: High cost - Low impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	SAP increase	Cost per SAP point increase
Photovoltaics (2 kWp) (PVs)	-21	G	11,500	3	3833.33
Wind turbine on stand-alone mast (5m diameter)	-11	G	20,000	13	1538.46
Solid Wall insulation (U-value 0.3) (SWI)	-8	G	9,000	16	562.50
Solid Fuel (SF) range boiler 67.5% + new HWC	2	G	8,500	26	326.92
Air Source Heat Pump (ASHP) + radiators + new HWC	3	G	8,000	27	296.30
Ground Source Heat Pump + new HWC	12	G	13,000	36	361.11
Oil condensing range 90% + new HWC	14	G	5,750	38	151.32
LI+ DP + SWI	14	G	9,450	38	248.68
Wood log boiler 80% + new HWC	16	G	8,750	40	218.75

Reducing Carbon Emissions in the Detached Bungalow

15.11 Similarly, the capital costs of the improvement options can be compared with their impact on the annual CO_{2e} emissions from this dwelling (see Figure 4.3 in the main report). The median cost of the improvements is £5450, and the median kg of CO_{2e} reduction per year is 21,604 kg of CO_{2e}.

CO_2 emissions: Low cost - High impact improvements in Detached Bungalow

15.12 When examined in terms of the impact on reducing carbon emissions from this dwelling, the Low cost – High impact sector is comprised of heating options. Changing the reliance on burning house coal in open fires will reduce the CO_{2e} emissions from this dwelling. As this dwelling is well off the gas grid, the fuel of choice for many parts of Scottish households (i.e. mains gas) is not an option.

15.13 The oil boiler, quantum storage heater, and electric wet thermal store improvements of the Low cost – High impact measures per SAP point again feature amongst the Low cost - High impact sector when costs are assessed against the CO_{2e} emission reductions (see Table A9.5). While the new high thermal capacity electric storage heaters (i.e. Quantum storage heaters) still feature here, the modern slimline form of storage heating drops out.

15.14 The oil boilers in this section are joined by the condensing combi boiler without any additional insulation being included within the improvement measure. No insulation package comes within this sector (because without a switch of heating they are still modelled with solid fuel and electric room heaters).

15.15 There is a relative degree of consistency in this sector – there is a limited variability in the capital costs (ranging from £3900 up to £5450, and the mean cost of reducing CO_{2e} by 1 kg per year here ranges between 15p per kg of CO_{2e} up to 23p per kg of CO_{2e} saved.

Table A9.5: CO_{2e} emissions: Low cost - High impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	Saving kg CO_{2e} / year	Cost per kg CO_{2e} reduced
Oil condensing combi 90.1%	13	G	5,000	22,483	0.22
Oil condensing combi 90.1% + LI	25	F	5,350	24,622	0.22
Oil condensing combi 90.1% + LI + DP	26	F	5,450	24,868	0.22
Oil condensing combi 90.1% + LI + DGA + DP doors	29	F	3,900	25,332	0.15
Quantum storage heaters + new HWC + LI + DP	31	F	4,000	21,948	0.18
Electric wet thermal store + damper + LI	32	F	4,400	22,299	0.20
Electric wet thermal store + LI + DP	33	F	4,550	22,628	0.20
Quantum storage heaters + new HWC + LI + DGA + DP doors + FI	38	F	5,450	23,475	0.23

CO_{2e} emissions: Low cost – Low impact improvements in the Detached Bungalow

15.16 Loft insulation and draught proofing are joined within the Low cost – Low impact quarter by floor insulation, as well as various heating improvements both with and without insulation in the package, and some of the renewable options (see Table A9.6).

15.17 Again, while loft insulation, on its own and in combination with draught proofing, is very good in terms of its cost per kg of CO_{2e} saved per year, at 5p per kg of CO_{2e} reduction, its overall impact is limited on reducing the total CO_{2e} emissions from this dwelling when compared to the impact of some of other measures in this sector.

15.18 As there is no minimum reduction in CO_{2e} associated with this group, the cost of saving a kg of CO_{2e} per year varies considerably within this group, from 5p per kg to almost £8 per kg of CO_{2e} saved per year.

Table A9.6: CO_{2e} emissions: Low cost – Low impact improvements in the Detached Bungalow

improvement(s) assessed	SAP	SAP Band	Capital cost	Saving kg CO_{2e} / year	Cost per kg CO_{2e} reduced
Fit baffle / damper on open fire (damper)	-23	G	50	502	0.10
Insulated doors (2 doors)	-23	G	1000	662	1.51
Fit damper on open fire + DP	-22	G	150	1335	0.11
Draught proof windows and doors (DP)	-22	G	100	854	0.12
Wind turbine on roof (2m diameter)	-22	G	2750	354	7.77

Floor insulation (U-value 0.25) (FI)	-20	G	1000	2145	0.47
Low-E Double Glazing (U-value 2.1) (DG)	-20	G	4650	2255	2.06
Low-E + Argon filled Double Glazing (U-value 1.8) (DGA)	-20	G	4650	2316	2.01
Electric wet central heating - direct electric on E10 tariff + new hot water cylinder (HWC)	-12	G	4000	18448	0.22
Electric wet central heating - direct electric on E10 tariff + new HWC + damper	-11	G	4050	20266	0.20
Loft insulation (U-value 0.13) (LI)	-10	G	350	7623	0.05
LI + DP	-9	G	450	8491	0.05
Electric room heater system on E10 tariff + new HWC	-8	G	2150	18151	0.12
Electric room heater system on E10 tariff + new HWC+ damper	-7	G	2200	21306	0.10
LI + DP + FI	-4	G	1450	10682	0.14
Electric wet central heating: CPSU on E18 tariff	4	G	4000	18304	0.22
Electric fan storage heating (auto) + panel heaters + new HWC + damper	6	G	2500	18201	0.14
Electric fan storage heating (auto) + new HWC	7	G	4050	15783	0.26
Electric wet central heating: CPSU + damper	7	G	2150	20078	0.11
Electric wet - water storage boiler (thermal store) on off peak tariff	14	G	4000	17413	0.23
Quantum storage heaters + new HWC	17	G	3550	18599	0.19
Electric fan storage heating (auto) + new HWC + LI	19	G	2500	19663	0.13
Electric wet thermal store on off peak E18 tariff + damper	20	G	4050	19348	0.21
Electric fan storage heating (auto charge control) + new HWC + LI + DP	21	F	2600	20104	0.13

CO_{2e} emissions: High cost - High impact improvements in the Detached Bungalow

15.19 The High cost – High impact quarter is comprised of changes in heating system and various insulation packages coupled with the changes in heating system or with renewables (see Table A9.7). There are no insulation only packages in this quarter.

15.20 While some of these improvements have a significant impact on the CO_{2e} emissions, they do not raise the SAP banding above Band G – various heat pump systems, an oil boiler and the wood log boiler, all without any additional insulation. By contrast other improvement options significantly reduce the CO_{2e} emissions and significantly increase the SAP banding to Band D.

15.21 This group demonstrates a narrow range amongst the costs associated with reducing the CO_{2e} emissions by 1 kg per year, ranging between 22p per kg to £1.44 per kg of CO_{2e} saved.

Table A9.7: CO_{2e} emissions: High cost – High impact improvements in the Detached Bungalow

improvement(s) assessed	SAP	SAP Band	Capital cost	saving kg CO_{2e} / year	cost per kg CO_{2e} reduced
Air Source Heat Pump (ASHP) + radiators + new HWC	3	G	8000	24933	0.32
Ground Source Heat Pump + new HWC	12	G	13000	26265	0.49
Oil condensing range 90% + new HWC	14	G	5750	22588	0.25
Wood log boiler 80% + new HWC	16	G	8750	29322	0.30
Oil condensing combi 90.1% + LI + DP	26	F	5450	24868	0.22
Quantum storage heaters + new HWC + LI	29	F	10050	21604	0.47
Insulation package + DGA + Solar hot water	30	F	20100	21870	0.92
Insulation package + DGA + Wind turbine on roof (2m diameter)	32	F	17850	21817	0.82
Quantum storage heaters + new HWC + LI + DGA + DP doors	34	F	10100	22589	0.45
Oil condensing combi 90.1% + LI + DGA + DP doors + FI	34	F	8650	25971	0.33
Insulation package + DGA + PVs	36	F	26600	22180	1.20
Electric wet thermal store + damper + LI + DGA + DP doors	37	F	9150	23285	0.39
Quantum storage heaters + new HWC + LI + DGA + DP doors + FI	38	F	5450	23475	0.23
Electric wet thermal store + damper + LI + DP + FI	38	F	9650	23487	0.41
Electric wet thermal store + damper + LI + DGA + DP doors + FI	41	E	10150	24155	0.42
Insulation package + DGA + ASHP + new HWC	48	E	23850	29613	0.81
Insulation package + DGA + Electric Storage Heating + new HWC	50	E	17250	26853	0.64
Insulation package + DGA + SF range 67.5% + new HWC	51	E	24350	25713	0.95
Insulation package + DGA + Electric Storage Heating + electric panel heaters + new HWC	53	E	17650	27485	0.64
Insulation package + DGA + oil condensing combi 90.1%	55	D	28100	28310	0.99
Insulation package + DGA + Ground Source Heat Pump	55	D	20100	30085	0.67
Insulation package + DGA + oil condensing range 90% + new HWC	58	D	20850	28567	0.73
Insulation package + Electric wet thermal store + damper	59	D	19150	27087	0.71
Insulation package + DGA + wood log boiler 80% + new HWC	60	D	25550	30693	0.83
Insulation package + DGA + Quantum storage heaters + new HWC	60	D	18650	27249	0.68
Insulation package + DGA + electric wet thermal store + damper	64	D	19150	27783	0.69
Insulation package + DGA + Wind turbine on mast (5m diameter)	68	D	35100	24362	1.44

CO_{2e} emissions: High cost - Low impact improvements in Detached Bungalow

15.22 The High cost – Low impact emissions quarter is comprised of the two renewable options without any additional insulation that were also included in the High cost – Low impact sector when costs were plotted against the improvement in the SAP score. On this occasion these options are joined by various insulation packages that include solid wall insulation but without any changes to the heating. Solid wall insulation is expensive, but without also tackling the heating in this dwelling, the carbon savings will be lower than the mean. The impact of the insulation is not enough to overcome the high emissions associated with the existing heating (see Table A9.8).

15.23 The costs per kg of CO_{2e} reduced per year range between 53p per kg of CO_{2e} per year (i.e. for the new solid fuel (i.e. house coal) range boiler – if it burned wood as its fuel then there would be significantly higher carbon savings) to over £16 per kg (i.e. solar PV panels).

Table A9.8: CO_{2e} emissions: High cost – Low impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	Saving kg CO_{2e} / year	Cost per kg CO_{2e} reduced
Photovoltaics (2 kWp) (PVs)	-21	G	11500	717	16.04
Wind turbine on stand-alone mast (5m diameter)	-11	G	20000	2899	6.90
Solid Wall insulation (U-value 0.3) (SWI)	-8	G	9000	8914	1.01
Solid Fuel (SF) range boiler 67.5% + new HWC	2	G	8500	14278	0.60
LI+ DP + SWI	14	G	9450	17563	0.54
Insulation package (LI + SWI + FI + DP)	22	F	10450	19752	0.53
Insulation package + DGA	28	F	15100	21463	0.70

Reducing Fuel Bills in the Detached Bungalow

15.24 The capital cost of the improvement options were compared with the reductions the SAP fuel bills (see Figure 4.4 of the main report). The median cost of the improvements is £5,450, and the median SAP fuel bill reduction is estimated at £1913 per year. As noted in the main report, the SAP scores and SAP fuel bills are directly related, so the improvement measures comprising Low cost – High impact, Low Cost – Low impact, High cost – High impact and High cost – Low impact groupings are identical to those seen when discussing the impact of the improvements on increasing the SAP scores.

Fuel bill reductions: Low cost - High impact improvements in Detached Bungalow

15.25 The Low cost - High impact sector of the fuel bill reductions versus capital costs comparison is comprised of various changes in the heating system usually coupled with loft insulation or loft insulation and draught proofing. The payback periods range between 1.3 and 2.6 years (see Table A9.9). All but two of the improvements here raise the dwelling into SAP Band of F.

Table A9.9: Reduced Fuel Bills: Low cost - High impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	Saving £/year	Payback (years)
Electric fan storage heating (auto) + new HWC + LI	19	G	2500	1913	1.3
Electric wet thermal store on off peak E18 tariff + damper	20	G	4050	1923	2.1
Electric fan storage heating (auto charge control) + new HWC + LI + DP	21	F	2600	1959	1.3
Oil condensing combi 90.1% + LI	25	F	5350	2062	2.6
Oil condensing combi 90.1% + LI + DP	26	F	5450	2100	2.6
Oil condensing combi 90.1% + LI + DGA + DP doors	29	F	3900	2173	1.8
Quantum storage heaters + new HWC + LI + DP	31	F	4000	2207	1.8
Electric wet thermal store + damper + LI	32	F	4400	2235	2.0
Electric wet thermal store + LI + DP	33	F	4550	2270	2.0
Quantum storage heaters + new HWC + LI + DGA + DP doors + FI	38	F	5450	2365	2.3

Fuel bill reductions: Low cost – Low impact improvements in Detached Bungalow

15.26 All of the single insulation measures have an impact on reducing the estimated fuel bills, but their impact is relatively low overall without addressing the heating system (see Table A9.10). Some of these options are not 'cheap' to install, although they fall within the low cost range of options for this dwelling.

15.27 The result is the wide variability in the associated payback periods seen in this quarter. The payback periods range from between 6 months (i.e. loft insulation) to over 125 years (i.e. solar hot water system). Despite the very good paybacks associated with many of the improvement options here (e.g. 18 of 32 of the improvement options have simple paybacks of less than 5 years; another 5 have paybacks of between 5 and 7 years), none are sufficient to raise the dwelling above its starting SAP Banding of G.

Table A9.10: Reduced Fuel Bills: Low cost - Low impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	Saving £/year	Payback (years)
Fit baffle / damper on open fire (damper)	-23	G	50	50	1.00
Insulated doors (2 doors)	-23	G	1000	66	15.2
Solar hot water panels (4m^2)	-23	G	5000	40	125.0
Fit damper on open fire + DP	-22	G	150	134	1.1
Draught proof windows and doors (DP)	-22	G	100	86	1.2

Wind turbine on roof (2m diameter)	-22	G	2750	90	30.6
Photovoltaics (2 kWp) (PVs)	-21	G	11500	182	63.2
Floor insulation (U-value 0.25) (FI)	-20	G	1000	215	4.7
Low-E Double Glazing (U-value 2.1) (DG)	-20	G	4650	226	20.6
Low-E + Argon filled Double Glazing (U-value 1.8) (DGA)	-20	G	4650	232	20.0
Electric wet central heating - direct electric on E10 tariff + new hot water cylinder (HWC)	-12	G	4000	665	6.0
Electric wet central heating - direct electric on E10 tariff + new HWC + damper	-11	G	4050	711	5.7
Wind turbine on stand-alone mast (5m diameter)	-11	G	20000	737	27.1
Loft insulation (U-value 0.13) (LI)	-10	G	350	765	0.5
LI + DP	-9	G	450	852	0.5
Electric room heater system on E10 tariff + new HWC	-8	G	2150	885	2.4
Solid Wall insulation (U-value 0.3) (SWI)	-8	G	9000	894	10.1
Electric room heater system on E10 tariff + new HWC+ damper	-7	G	2200	934	2.4
LI + DP + FI	-4	G	1450	1072	1.4
Solid Fuel (SF) range boiler 67.5% + new HWC	2	G	8500	1320	6.4
Air Source Heat Pump (ASHP) + radiators + new HWC	3	G	8000	1354	5.9
Electric wet central heating: CPSU on E18 tariff	4	G	4000	1397	2.9
Electric fan storage heating (auto) + panel heaters + new HWC + damper	6	G	2500	1463	1.7
Electric fan storage heating (auto) + new HWC	7	G	4050	1513	2.7
Electric wet central heating: CPSU + damper	7	G	2150	1512	1.4
Ground Source Heat Pump + new HWC	12	G	13000	1692	7.7
Oil condensing combi 90.1%	13	G	5000	1737	2.9
Electric wet - water storage boiler (thermal store) on off peak tariff	14	G	4000	1756	2.3
Oil condensing range 90% + new HWC	14	G	5750	1757	3.3
LI+ DP + SWI	14	G	9450	1762	5.4
Wood log boiler 80% + new HWC	16	G	8750	1821	4.8
Quantum storage heaters + new HWC	17	G	3550	1861	1.9

Fuel bill reductions: High cost - High impact improvements in Detached Bungalow

15.28 The largest reductions in fuel bills are seen where the insulation and double glazing package is usually coupled with the improvements in the heating system for this dwelling, or coupled with renewable and low carbon technologies, but these come at a cost (see Table 8.11), thus, being found in the High impact – High cost group.

15.29 However, despite the high costs, the payback periods range between 2.3 years and 11.4 years. Eight of the 25 options here have payback periods of less than 5 years; another 7 have payback periods of between 5 and 7 years.

Table A9.11: Reduced Fuel Bills: High cost - High impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	Saving £/year	Payback (years)
Insulation package (LI + SWI + FI + DP)	22	F	10450	1982	5.3
Oil condensing combi 90.1% + LI + DP	26	F	5450	2100	2.6
Insulation package + DGA	28	F	15100	2154	7.0
Quantum storage heaters + new HWC + LI	29	F	10050	2171	4.6
Insulation package + DGA + Solar hot water	30	F	20100	2197	9.1
Insulation package + DGA + Wind turbine on roof (2m diameter)	32	F	17850	2244	8.0
Quantum storage heaters + new HWC + LI + DGA + DP doors	34	F	10100	2273	4.4
Oil condensing combi 90.1% + LI + DGA + DP doors + FI	34	F	8650	2272	3.8
Insulation package + DGA + PVs	36	F	26600	2336	11.4
Electric wet thermal store + damper + LI + DGA + DP doors	37	F	9150	2340	3.9
Quantum storage heaters + new HWC + LI + DGA + DP doors + FI	38	F	5450	2365	2.3
Electric wet thermal store + damper + LI + DP + FI	38	F	9650	2361	4.1
Electric wet thermal store + damper + LI + DGA + DP doors + FI	41	E	10150	2432	4.2
Insulation package + DGA + ASHP + new HWC	48	E	23850	2543	9.4
Insulation package + DGA + Electric Storage Heating + new HWC	50	E	17250	2584	6.7
Insulation package + DGA + SF range 67.5% + new HWC	51	E	24350	2598	9.4
Insulation package + DGA + Electric Storage Heating + electric panel heaters + new HWC	53	E	17650	2627	6.7
Insulation package + DGA + oil condensing combi 90.1%	55	D	28100	2665	10.5
Insulation package + DGA + Ground Source Heat Pump	55	D	20100	2663	7.5
Insulation package + DGA + oil condensing range 90% + new HWC	58	D	20850	2713	7.7
Insulation package + Electric wet thermal store + damper	59	D	19150	2743	7.0
Insulation package + DGA + wood log boiler 80% + new HWC	60	D	25550	2751	9.3
Insulation package + DGA + Quantum storage heaters + new HWC	60	D	18650	2754	6.8
Insulation package + DGA + electric wet thermal store + damper	64	D	19150	2816	6.8
Insulation package + DGA + Wind turbine on mast (5m diameter)	68	D	35100	2890	12.1

15.30 What is interesting is that amongst the improvements recording the highest impact on the fuel bill, are several variations on electric heating – both an electric wet thermal store heating system and the new, high thermal capacity (Quantum) storage heaters, in conjunction with comprehensive insulation packages.

15.31 The impacts of these packages are such that not only do all of them achieve at least a SAP Banding of F, many will raise the SAP rating to Band E, and even to Band D.

Fuel bill reductions: High cost - Low impact improvements in the Detached Bungalow

15.32 High cost measures do not necessarily equate to large reductions in fuel bills (see Table A9.12). Conversely high capital costs do not necessarily mean long payback periods. The payback periods for the High cost - Low impact improvements range between 3.3 years and 63.3 years.

15.33 This payback does not take account of any benefit of payments that may occur through FiTs or RHI, which, if factored in, would significantly change the payback periods for renewable, heat pump and wood log boiler options that fall within this sector.

15.34 The improvements in this sector are not sufficient on their own to raise the SAP score of this dwelling above its existing ‘G’ banding.

Table A9.12: Reduced Fuel Bills: High cost - Low impact improvements in the Detached Bungalow

Improvement(s) assessed	SAP	SAP Band	Capital cost	Saving £/year	Payback (years)
Photovoltaics (2 kWp) (PVs)	-21	G	£11,500	182	63.2
Wind turbine on stand-alone mast (5m diameter)	-11	G	£20,000	737	27.1
Solid Wall insulation (U-value 0.3) (SWI)	-8	G	£9,000	894	10.1
Solid Fuel (SF) range boiler 67.5% + new HWC	2	G	£8,500	1320	6.4
Air Source Heat Pump (ASHP) + radiators + new HWC	3	G	£8,000	1354	5.9
Ground Source Heat Pump + new HWC	12	G	£13,000	1692	7.7
Oil condensing range 90% + new HWC	14	G	£5,750	1757	3.3
LI+ DP + SWI	14	G	£9,450	1762	5.4
Wood log boiler 80% + new HWC	16	G	£8,750	1821	4.8

Overall Comment on the Improvements Assessed for the Detached Dwelling

15.35 Many of the measures that make up the low cost – high impact; high cost – high impact; low cost – low impact; and high cost – low impact quarters for this dwelling, regardless of whether assessed on impact on the dwelling’s

SAP score, the reduction in CO_{2e} emissions, or the reductions in fuel bills, are the same in each quarter. There are a few measures that shift about. From one aspect, that is good in that the same measures would feature in packages whether you tackle fuel bills, CO_{2e} emissions or the SAP score. Within this consistency there is a great variability in some groups in terms of the cost of SAP point increase, cost of saving a kg of CO_{2e}, or the payback period. High cost improvements are not necessarily poor in terms of their impact or their returns; low cost investments are not necessarily good in terms of their impact or their returns.

Improving the Top Floor Tenemental Flat

15.36 Similar analysis was performed on a 1920's solid walled, tenemental, gable end flat within an urban area of Scotland, with 50 separate improvement options (i.e. individual improvements or combinations of individual improvements) being assessed. What emerged immediately was that compared to the detached bungalow off the gas grid, the presence of a gas supply in this dwelling completely changed the dynamics of the improvements. For example, simply fitting a gas condensing combi boiler as a single measure would increase the SAP score from '4' to '55', i.e. in itself raise the SAP Banding of G to Band D.

15.37 The increases in the SAP score, the reductions in kg of CO_{2e} emissions, and the reductions in SAP fuel bills were plotted against the mean capital cost of the various improvements in Figures 4.6, 4.7 and 4.8 respectively in the main report. The median of cost of the improvements assessed for this dwelling (i.e. £3,261.50) and the median change in the respective SAP score (i.e. 41 SAP points), the reduction in Kg of CO_{2e} per year (i.e. 1,970 kg of CO_{2e}), the reduction in £ per year on the SAP fuel costs (i.e. £890) were used to define the axes in these graphs, quartering the graph into low cost - low impact, low cost – high impact, high cost – low impact, and high cost - high impact sections.

Low cost - High impact improvements in Top Floor Tenemental Flat

15.38 Only one measure falls within the Low cost - High impact sector across all performance assessments of improving the SAP rating, reducing CO_2 emissions and cutting household fuel costs: the fitting of the new high heat retention (Quantum) storage heaters in conjunction with loft insulation and draught proofing the door (see Tables A9.13 – A9.15). Modern slimline storage heating system on a 24-hour tariff, coupled with loft insulation, draught proofing the front door, and fitting a new hot water cylinder jacket, show up well on improving the SAP score and reducing the fuel bill, but not so well on reducing CO_{2e} emissions because of the higher CO_{2e} conversion co-efficient with electric heating compared to gas.

Table A9.13: SAP rating: Low cost – High impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Increase in SAP score	Cost per SAP point increase (£)
Quantum storage heaters + LI	45	E	£3,150	41	76.83
Quantum storage heaters + LI + DPd	45	E	£3,250	41	79.27
ESH E24 + LI	47	E	£1,950	43	45.35
ESH E24 + LI + DPd	47	E	£2,050	43	47.67
ESH E24 + LI + DPd + HWTJ	49	E	£2,073	45	46.07
ESH E24 + LI + DPd + HWTJ + CFLs	50	E	£2,098	46	45.61

Table A9.14: CO_{2e} emissions: Low cost - High impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Saving kg CO_{2e} / year	Cost per Kg CO_{2e} saved per year (£)
LI + DPd + HWTJ	25	F	£478	2117	0.23
LI + DPd + HWTJ + CFLs	26	F	£498	2173	0.23
Quantum storage heaters + LI	45	E	£3,150	2036	1.55
Quantum storage heaters + LI + DPd	45	E	£3,250	2047	1.59

Table A9.15: Fuel Bill Savings: Low cost - High impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Saving in fuel bill (£/year)	Payback (years)
Quantum storage heaters + LI + DPd	45	E	£3,250	891	3.6
ESH E24 + LI	47	E	£1,950	924	2.1
ESH E24 + LI + DPd	47	E	£2,050	926	2.2
ESH E24 + LI + DPd + HWTJ	49	E	£2,073	951	2.2
ESH E24 + LI + DPd + HWTJ + CFLs	50	E	£2,098	968	2.2

Low cost - Low impact improvements in Top Floor Tenemental Flat

15.39 The Low cost – Low impact improvements (see Tables A9.3.16 – A9.18) display great variability. Loft insulation, hot water cylinder insulation, draught proofing of the door, and low energy light bulbs are here as single measures, in combined packages, and in combination with various types of electric storage heating. Other improvements common across the various performance assessments are the small wind turbine, and various storage heating systems.

15.40 The cost of improving the SAP rating by 1 point varies considerably, ranging from £19.44 per 1 point increase up to £2,750 (see Table A9.16). Loft insulation on its own is the most cost effective measure in terms of raising the SAP rating; the small wind turbine, the most expensive item.

Table A9.16: SAP Rating: Low cost - Low impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Increase in SAP score	Cost per SAP point increase (£)
low energy light bulbs (LELs)	5	G	25	1	25
Draught proofing door (DPd)	5	G	100	1	100
Insulated door (U-value 1.0)	5	G	500	1	500
Hot water tank jacket 80mm (HWTJ)	5	G	23	1	23
Wind turbine on roof (2m diameter)	5	G	2750	1	2750
Electric storage heating system auto control on E7 (ESH E7)	20	G	1400	16	87
Loft insulation (U-value 0.13) (LI)	22	F	350	18	19
LI + DPd	22	F	450	18	25
ESH E7 + HWTJ	22	F	1423	18	79
LI + DPd + HWTJ	25	F	478	21	23
LI + DPd + HWTJ + CFLs	26	F	498	22	23
Electric storage heating system auto control on E24 (ESH E24)	29	F	1600	25	64
ESH E24 + HWTJ	30	F	1623	26	62
Quantum storage heaters	31	F	2800	27	104
Quantum storage heater + HWTJ	35	F	2823	31	91
ESH E7 + LI	36	F	1750	32	55
ESH E7 + LI + DPd	37	F	1850	33	56
ESH E7 + LI + DPd + HWTJ	40	E	1878	36	52
ESH E7 + LI + DPd + HWTJ + CFLs	42	E	1898	38	50
Quantum storage heaters + LI	45	E	3150	41	77
Quantum storage heaters + LI + DPd	45	E	3250	41	79

15.41 Unlike the situation within the detached bungalow, both single insulation improvements, and heating improvements without any additional insulation, are sufficient on their own to increase the SAP score enough to achieve Band F (see Table A9.16).

15.42 The cost per kg of CO_{2e} saved per year range from 11p per kg of CO_{2e} saved per year to over £24 (see Table A9.17). The hot water cylinder jacket and the loft insulation are most cost-effective measures here.

15.43 Several of the measures in Table A9.17 actually display a negative impact on CO_{2e} emissions. All of these measures relate to the installation of electric storage heating where no fabric insulation was included in the package (although two of them do include hot water cylinder jackets). Although both direct electric heating and electric storage heating are considered 100% efficient at end use in SAP, storage heating is less responsive than direct acting electric heater, and is therefore penalised within the SAP methodology, so that despite being cheaper to use than direct electric heating, electric storage heating consumes more energy overall and therefore has higher emissions associated with it.

Table A9.17: CO_{2e} Emissions: Low cost - Low impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Saving kg CO_{2e} / year	Cost per Kg CO_{2e} saved per year (£)
low energy light bulbs (LELs)	5	G	25	58	0.43
Draught proofing door (DPd)	5	G	100	12	8.33
Insulated door (U-value 1.0)	5	G	500	101	4.95
Hot water tank jacket 80mm (HWTJ)	5	G	23	217	0.11
Wind turbine on roof (2m diameter)	5	G	2,750	113	24.34
Electric storage heating system auto control on E7 (ESH E7)	20	G	1,400	-1,264	-1.11
Loft insulation (U-value 0.13) (LI)	22	F	350	1,892	0.18
LI + DPd	22	F	450	1,904	0.24
ESH E7 + HWTJ	22	F	1,423	-724	-1.97
Electric storage heating system auto control on E24 (ESH E24)	29	F	1,600	-871	-1.84
ESH E24 + HWTJ	30	F	1,623	-729	-2.23
Quantum storage heaters	31	F	2,800	190	14.74
Quantum storage heater + HWTJ	35	F	2,823	407	6.94
ESH E7 + LI	36	F	1,750	1,286	1.36
ESH E7 + LI + DPd	37	F	1,850	1,302	1.42
ESH E7 + LI + DPd + HWTJ	40	E	1,878	1,486	1.26
ESH E7 + LI + DPd + HWTJ + CFLs	42	E	1,898	1,530	1.24
ESH E24 + LI	47	E	1,950	1,478	1.32
ESH E24 + LI + DPd	47	E	2,050	1,492	1.37
ESH E24 + LI + DPd + HWTJ	49	E	2,073	1,685	1.23
ESH E24 + LI + DPd + HWTJ + CFLs	50	E	2,098	1,733	1.21

15.44 The payback periods range from less than 5 months to over 94 years (see Table A9.18). Again, loft insulation and the hot water cylinder jacket are at one end of the scale, and the wind turbine at the other. The various electric storage heating systems have payback periods ranging from 2.5 years up to 4 years.

Table A9.18: Fuel Bill Savings: Low cost - Low impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	saving in fuel bill (£/year)	payback (years)
low energy light bulbs (LELs)	5	G	25	15	1.7
Draught proofing door (DPd)	5	G	100	3	33.3
Insulated door (U-value 1.0)	5	G	500	26	19.2
Hot water tank jacket 80mm (HWTJ)	5	G	23	55	0.4
Wind turbine on roof (2m diameter)	5	G	2750	29	94.8

Electric storage heating system auto control on E7 (ESH E7)	20	G	1400	416	3.4
Loft insulation (U-value 0.13) (LI)	22	F	350	481	0.7
LI + DPd	22	F	450	484	0.9
ESH E7 + HWTJ	22	F	1423	481	3.0
LI + DPd + HWTJ	25	F	478	538	0.9
LI + DPd + HWTJ + CFLs	26	F	498	552	0.9
Electric storage heating system auto control on E24 (ESH E24)	29	F	1600	629	2.5
ESH E24 + HWTJ	30	F	1623	649	2.5
Quantum storage heaters	31	F	2800	659	4.2
Quantum storage heater + HWTJ	35	F	2823	729	3.9
ESH E7 + LI	36	F	1750	759	2.3
ESH E7 + LI + DPd	37	F	1850	761	2.4
ESH E7 + LI + DPd + HWTJ	40	E	1878	826	2.3
ESH E7 + LI + DPd + HWTJ + CFLs	42	E	1898	845	2.2
Quantum storage heaters + LI	45	E	3150	889	3.5

15.45 Even amongst the low impact improvements in Table A9.18, the impact of the majority of improvements here is sufficient to reduce the household fuel bill by more than £10 a week.

High cost - High impact improvements – Top Floor Tenemental Flat

15.46 Amongst the High cost – High impact options assessed for this top floor tenemental flat (see Tables A9.19 – A9.20), the range of measures across the increase in the SAP score and reductions in CO_{2e} emissions and fuel costs are dominated by the comprehensive insulation package either on its own or in combination with a heating system improvement or the addition of renewables. Only two measures here do not include insulation: i.e. a condensing gas combi boiler system as a single measure, or one fitted with flue gas heat recovery (FGHRS). All of these options achieve at least a SAP Banding of E or better; some improvement options achieve Band C.

15.47 The cost per increasing the SAP score here ranged from about £70 per point increase to over £280 per point increase, with the gas condensing combi boiler with loft insulation at the low end, and the comprehensive insulation package with PVs at the high end (see Table A9.19).

Table A9.19: SAP rating: High cost – High impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Increase in SAP score	Cost per SAP point increase (£)
Insulation package (LI SWI DPd LELs HWTJ)	49	E	9498	45	211.07
Quantum storage heaters + LI + DPd + HWTJ	50	E	3273	46	71.15
ASHP + LI	50	E	8850	46	192.39

ASHP + LI + DPd	50	E	8950	46	194.57
Insulation package + Wind turbine on roof (2m diameter)	51	E	12248	47	260.60
Quantum storage heaters + LI + DPd + HWTJ + CFLs	51	E	3298	47	70.17
ASHP + LI + DPd + CFLs	52	E	8975	48	186.98
Gas condensing combi 88% (GCC)	55	D	5000	51	98.04
Insulation package + Solar hot water	55	D	14498	51	284.27
GCC + Flue Gas Heat Recovery System (FGHRS)	56	D	5450	52	104.81
Insulation package + ESH E7	61	D	10898	57	191.19
Insulation package + PVs	62	D	20998	58	362.03
GCC + LI	65	D	5350	61	87.70
GCC + LI + DPd	65	D	5450	61	89.34
Insulation package + Quantum storage heaters	65	D	12298	61	201.61
GCC + LI + DPd + CFLs	66	D	5475	62	88.31
Insulation package + ASHP	67	D	11798	63	187.27
Insulation package + ESH E24	67	D	11098	63	176.16
Insulation package + GCC	74	C	14498	70	207.11
Insulation package + GCC + FGHRS	75	C	14998	71	211.24

15.48 The cost per reducing CO_{2e} emissions amongst the High cost – High impact measures ranged from about £1.23 per kg of CO_{2e} reduced to over £4.70, with the gas condensing combi boiler in combination with various low cost measures at the low end. The most expensive option with regard to reducing CO_{2e} was fitting the air source heat pump system as a single measure (see Table A9.20).

Table A9.20: CO_{2e} emissions: High cost – High impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Saving kg CO_{2e} / year	Cost per Kg CO_{2e} saved per year (£)
Air source heat pump (ASHP) + new Hot water cylinder	34	F	8,500	2,786	3.05
Insulation package (LI SWI DPd LELs HWTJ)	49	E	9,498	3,740	2.54
Quantum storage heaters + LI + DPd + HWTJ	50	E	3,273	2,262	1.45
ASHP + LI	50	E	8,850	3,808	2.32
ASHP + LI + DPd	50	E	8,950	3,815	2.35
Insulation package + Wind turbine on roof (2m diameter)	51	E	12,248	3,854	3.18
Quantum storage heaters + LI + DPd + HWTJ + CFLs	51	E	3,298	2,317	1.42
ASHP + LI + DPd + CFLs	52	E	8,975	3,887	2.31
Gas condensing combi 88% (GCC)	55	D	5,000	3,503	1.43
Insulation package + Solar hot water	55	D	14,498	4,088	3.55
GCC + Flue Gas Heat Recovery System (FGHRS)	56	D	5,450	3,623	1.50

Insulation package + ESH E7	61	D	10,898	3,513	3.10
Insulation package + PVs	62	D	20,998	4,457	4.71
GCC + LI	65	D	5,350	4,351	1.23
GCC + LI + DPd	65	D	5,450	4,356	1.25
Insulation package + Quantum storage heaters	65	D	12,298	3,827	3.21
GCC + LI + DPd + CFLs	66	D	5,475	4,432	1.24
Insulation package + ASHP	67	D	11,798	4,738	2.49
Insulation package + ESH E24	67	D	11,098	3,584	3.10
Insulation package + GCC	74	C	14,498	5,137	2.82
Insulation package + GCC + FGHRS	75	C	14,998	5,209	2.88

15.49 The payback periods in terms of recouping the capital costs through savings in the fuel bills amongst this sector ranged from 3.4 years to over 18.5 years. The gas condensing combi boiler, in combination with various low cost improvements, is at the low end, and the comprehensive insulation package in combination with the PVs at the more expensive end (see Table A9.21).

Table A9.21: Fuel Bill Savings: High cost – High impact improvements Top Floor Flat

Improvement assessed	**SAP**	**SAP EPC Band**	**Capital cost (£)**	**Saving in fuel bill (£/year)**	**Payback (years)**
Insulation package (LI SWI DPd LELs HWTJ)	49	E	9,498	951	10.0
Quantum storage heaters + LI + DPd + HWTJ	50	E	3,273	961	3.4
ASHP + LI	50	E	8,850	968	9.1
ASHP + LI + DPd	50	E	8,950	969	9.2
Insulation package + Wind turbine on roof (2m diameter)	51	E	12,248	979	12.5
Quantum storage heaters + LI + DPd + HWTJ + CFLs	51	E	3,298	981	3.4
ASHP + LI + DPd + CFLs	52	E	8,975	988	9.1
Gas condensing combi 88% (GCC)	55	D	5,000	1,037	4.8
Insulation package + Solar hot water	55	D	14,498	1,039	14.0
GCC + Flue Gas Heat Recovery System (FGHRS)	56	D	5,450	1,051	5.2
Insulation package + ESH E7	61	D	10,898	1,111	9.8
Insulation package + PVs	62	D	20,998	1,133	18.5
GCC + LI	65	D	5,350	1,169	4.6
GCC + LI + DPd	65	D	5,450	1,170	4.7
Insulation package + Quantum storage heaters	65	D	12,298	1,170	10.5
GCC + LI + DPd + CFLs	66	D	5,475	1,190	4.6
Insulation package + ASHP	67	D	11,798	1,204	9.8
Insulation package + ESH E24	67	D	11,098	1,204	9.2
Insulation package + GCC	74	C	14,498	1,304	11.1
Insulation package + GCC + FGHRS	75	C	14,998	1,316	11.4

High cost - Low impact improvements – Top Floor Tenemental Flat

15.50 Amongst the improvement options that consistently scored as High cost – Low impact measures in the top floor tenemental flat, regardless of the variable assessed, were the installation of PVs, solar panels for hot water, high performance replacement double glazing and solid wall insulation on its own (see Tables A9.22 – A9.24). The solid wall insulation option was the best performing of these options in terms of the cost per 1 SAP point increase, saving a Kg of CO_{2e}, and payback period; replacing the existing standard double glazing with high performance double glazing was the worst performing option.

Table A9.22: SAP rating: High cost – Low impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Increase in SAP score	Cost per SAP point increase (£)
Low-e + Argon-filled DG (U-value 1.8) (DGA)	6	G	4,650	2	2325.00
Solar hot water (4m^2)	9	G	5,000	5	1000.00
Photovoltaics (2 kWp)	11	G	11,500	7	1642.86
Solid Wall insulation (U-value 0.3) (SWI)	18	G	9,000	14	642.86
Air source heat pump (ASHP) + new Hot water cylinder	34	F	8,500	30	283.33

Table A9.23: CO_{2e} emissions: High cost – Low impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Saving kg CO_{2e} / year	Cost per Kg CO_{2e} saved per year (£)
Low-e + Argon-filled DG (U-value 1.8) (DGA)	6	G	4,650	125	37.20
Solar hot water (4m^2)	9	G	5,000	566	8.83
Photovoltaics (2 kWp)	11	G	11,500	717	16.04
Solid Wall insulation (U-value 0.3) (SWI)	18	G	9,000	1472	6.11

Table A9.24: Fuel Bill Savings: High cost – Low impact improvements Top Floor Flat

Improvement assessed	SAP	SAP EPC Band	Capital cost (£)	Saving in fuel bill (£/year)	Payback (years)
Low-e + Argon-filled DG (U-value 1.8) (DGA)	6	G	4,650	32	145.3
Solar hot water (4m^2)	9	G	5,000	144	34.7
Photovoltaics (2 kWp)	11	G	11,500	182	63.2
Solid Wall insulation (U-value 0.3) (SWI)	18	G	9,000	374	24.1
Air source heat pump (ASHP) + new Hot water cylinder	34	F	8,500	708	12.0

15.51 The poor financial performance of PVs, the solar panels for hot water, and the air source heat pump here may be different if FiTs and RHI payments were factored into this assessment.

Overall Comment on the Improvements Assessed for the Top Floor Tenemental Flat

15.52 The presence of a mains gas supply changes the fundamental nature of the improvement package compared to the assessment of the detached bungalow which was off the gas grid. Installing a condensing boiler as a single measure would achieve a SAP D Band rating, and in combination with insulation measures could achieve a C rating.

15.53 As with the detached bungalow, there was a general consistency with the measures emerging from the assessment falling into the respective Low cost – High impact, Low cost – Low impact, High cost - High impact, and High cost – Low impact groupings for this property.

15.54 There is also consistency within this dwelling that some measures are extremely cost effective but do not have a huge impact in terms of raising the overall SAP rating. There is also a consistency in measures that are very expensive and do not make a big impact on the rating, or the reductions in CO_{2e} emissions, and have a long payback period.

Overall Comment

15.55 The use of the median values of the capital costs and the median values of the impacts of the different performance variables, i.e. the increase in SAP points, reductions in CO_{2e} emissions and reductions in fuel costs, in these two dwellings defined different thresholds for establishing the low cost – high impact, low impact – low cost, high impact - high cost, and high cost – low impact quartering of improvements for the two properties. They are self-defined by the improvement measures themselves, and by the improvements appropriate to the dwelling; they are not an objective standard. Yet what emerged was the consistency in the measures making up the different quarters, not only for the same property but in the two very different dwellings here.

15.56 Some improvements will always have a low impact; some improvements have a high installation cost. Neither impact nor indicative capital cost on their own define whether an improvement is a good investment or not.

16 APPENDIX 10: TURNOVER RATES IN THE OWNER OCCUPIED AND PRIVATE RENTED SECTOR

16.1 The following appendix was produced by Oscar Guinea and Adam Krawczyk at the Scottish Government to help estimate turnover rates among the target stock.

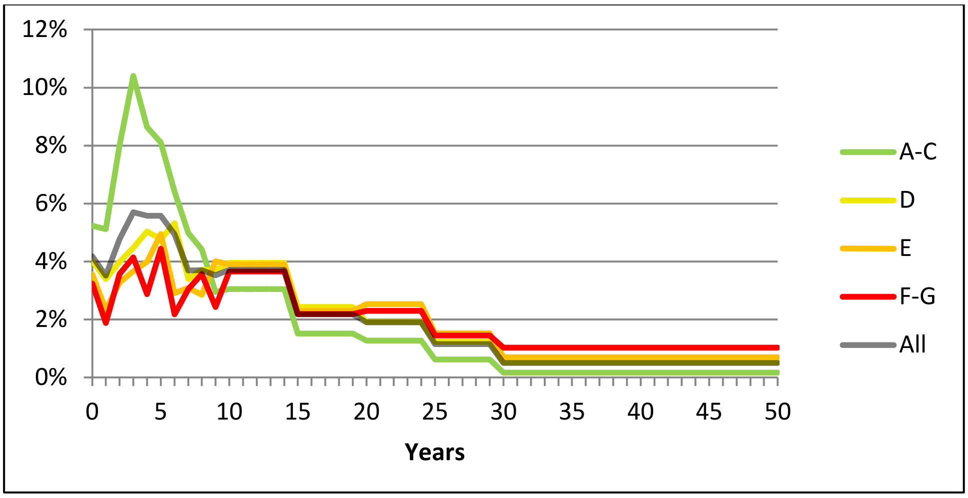
Length of tenure

16.2 The Scottish House Condition Survey (SHCS) asks respondents for the number of years they have been living in the property. SHCS data for 2011-2013 (three years) was used to calculate the length of tenure in the owner occupied sector (OO) and the private rented sector (PRS) by EPC band.

16.3 The advantages of using SHCS data are:

- Methodological consistency across OO and PRS
- Possibility to break down the results by EPC band.
- Possibility to produce the results by individual years to estimate a profile of sales within a period of time.

Figure A10.1: Length of tenure in the OO by EPC band and year

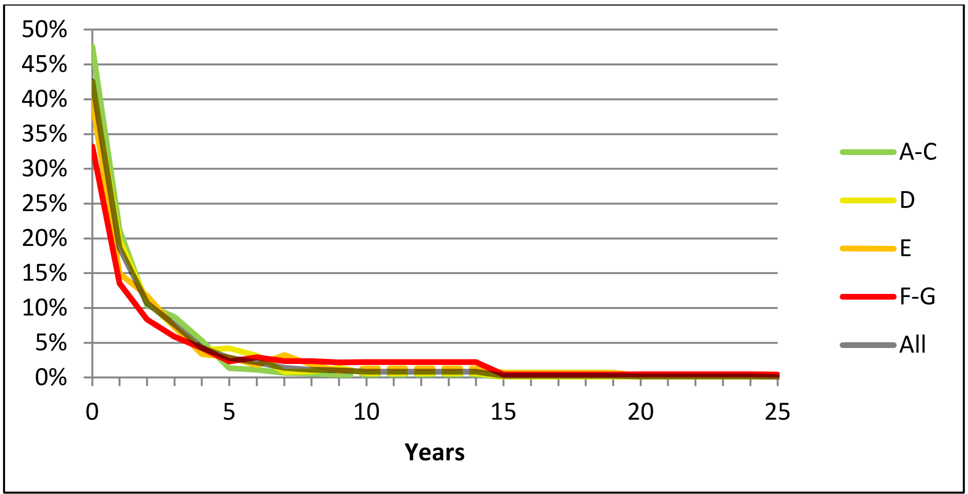


16.4 For households staying in their properties for more than 10 years, SHCS data is produced in 5-year bands while the last category is more than 30-year. We have adjusted this dividing the 5-year bands by 5 while the more than 30-year category was divided by 20 to produce a 50 years period. The original data on the length of tenure by EPC is presented in Tables 10.2 to 10.5.

16.5 For the OO sector, it needs to be noted that 21% of properties with an EPC of F and G and 14% of properties with an EPC of E have a length of tenure of more than 30 years. This might be relevant for specifying an backstop date.

16.6 The same approach is applied for the PRS. It is worth highlighting the high turnover rate in the private rented sector with 40% of E and 33% of F and G properties with a turnover of less than year. The fast turnover rate means that 88% of properties with an EPC of E and 77% of properties with an EPC of F and G will be on the market for rent and therefore will be subjected to REEPS before 10 years.

Figure A10.2: Length of tenure in the PRS by EPC band and year



16.7 Length of tenure as a proxy for turnover can be used to calculate the rate at which properties in the OO and PRS are impacted by REEPS. For example the SHCS show us that in the first year of REEPS 4% of EPC E properties in the OO and 40% in the PRS will be sold or rented, and depending on the secenario, will need to be upgraded.

16.8 In the second phase of the REEPS study, Ipsos MORI and Alembic Research produced a breakdown of properties in the private sector by EPC band.

Table A10.1: Breakdown of EPC bands among private sector stock in bands EFG.

	Percentage of dwellings	**Dwellings**	**OO**		**PRS**	
			dwellings	%	dwellings	%
EPC band E (39-54)	57.4%	229,840	194,158	60%	35,682	46%
EPC band F (21-38)	35.2%	141,032	110,904	34%	30,128	39%
EPC band G (0-20)	7.4%	29,676	17,776	6%	11,900	15%
All	100%	400,548	322,838	100%	77,710	100%

16.9 Applying length of tenure to the figures in Table A10.1 produces a profile of the number of properties that will be upgraded as a result of REEPS. These results are contained in tables A10.2 to A10.5. The following graphs show the cumulative number of properties impacted by REEPS per year for the first three scenarios as specified in REEPS. The boxes below higlight from which year the cumulative number of properties reaches 50% and 75% of all properties which are subjected to REEPS under each scenario.

Figure A10.3: Scenario 1: All dwellings to reach Band F

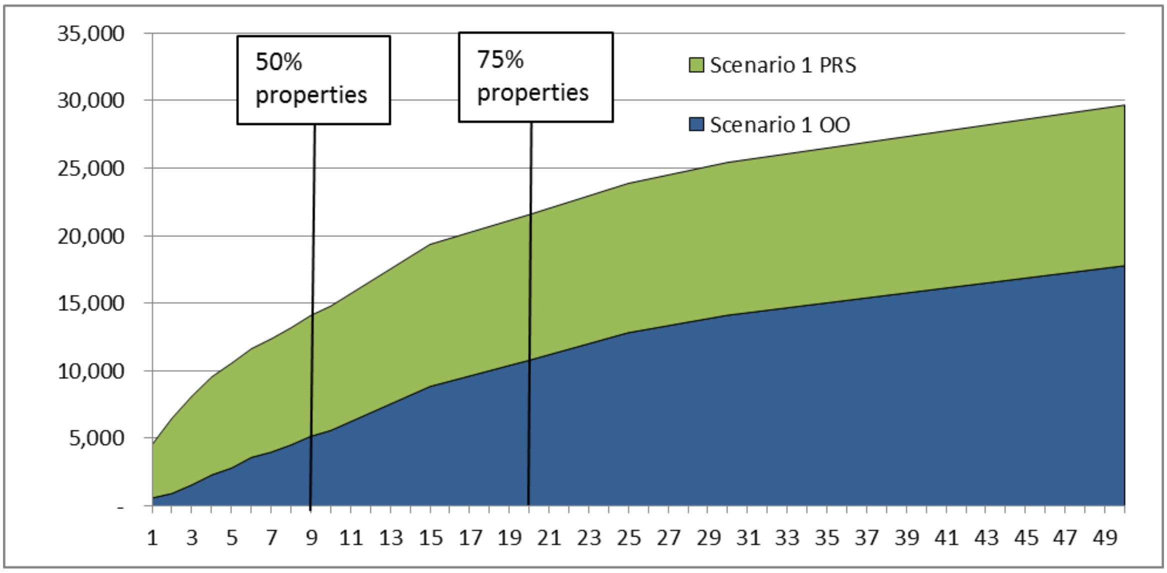


Figure A10.4: Scenario 1: All dwellings to reach Band E

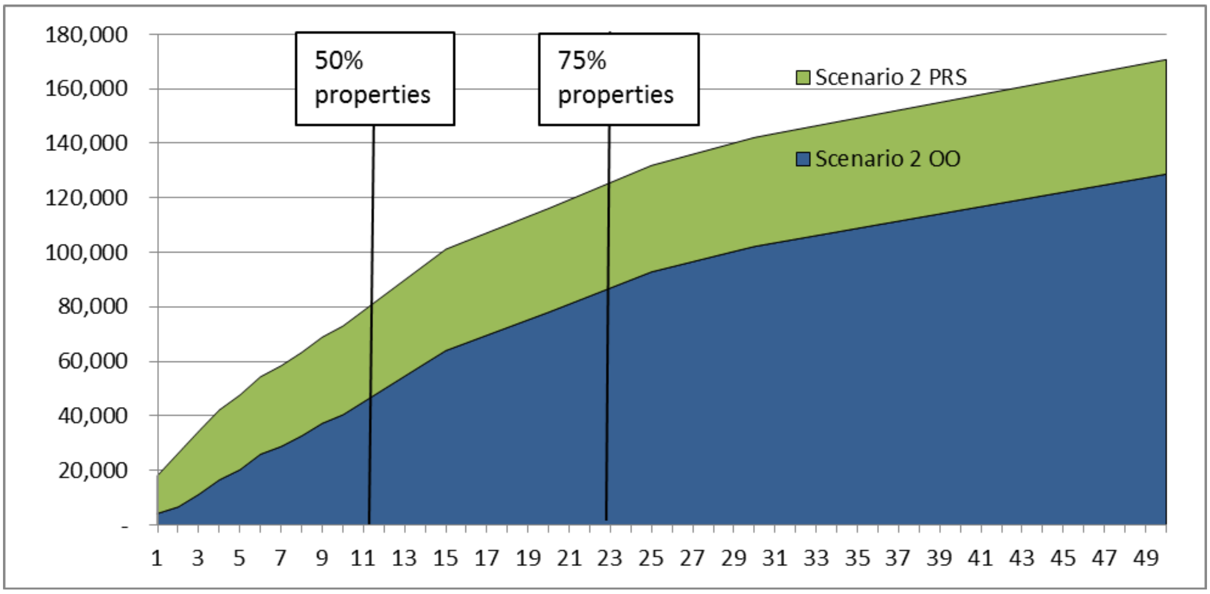


Figure A10.5: Scenario 1: All dwellings to reach Band D

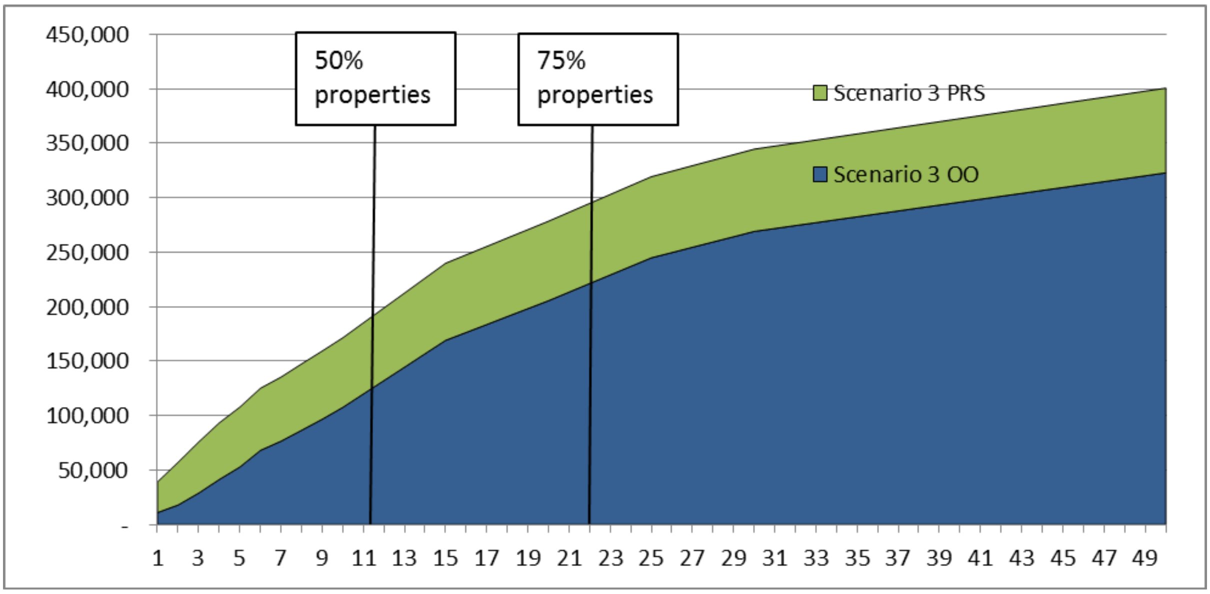


Table A10.2: Owner-occupied: Proportion length of stay by EPC band

	A-C	D	E	F-G	All
<1year	5%	4%	4%	3%	4%
1<2 years	5%	3%	2%	2%	4%
2<3 years	8%	4%	3%	4%	5%
3<4 years	10%	4%	4%	4%	6%
4<5 years	9%	5%	4%	3%	6%
5<6 years	8%	5%	5%	4%	6%
6<7 years	6%	5%	3%	2%	5%
7<8 years	5%	3%	3%	3%	4%
8<9 years	4%	4%	3%	4%	4%
9<10 years	3%	4%	4%	2%	4%
10<15 years	15%	20%	20%	18%	19%
15<20 years	8%	12%	12%	11%	11%
20<25 years	6%	10%	13%	11%	10%
25<30 years	3%	6%	8%	7%	6%
30+ years	3%	11%	14%	21%	10%

Table A10.3: Owner-occupied: Cumulative length of stay by EPC band

	A-C	D	E	F-G	All
<1year	5%	4%	4%	3%	4%
1<2 years	10%	7%	6%	5%	8%
2<3 years	18%	11%	9%	9%	12%
3<4 years	29%	16%	13%	13%	18%
4<5 years	37%	21%	17%	16%	24%
5<6 years	46%	26%	22%	20%	29%
6<7 years	52%	31%	25%	22%	34%
7<8 years	57%	34%	28%	25%	38%
8<9 years	61%	38%	31%	29%	42%
9<10 years	64%	42%	35%	31%	45%
10<15 years	80%	62%	54%	50%	64%
15<20 years	87%	74%	66%	61%	75%
20<25 years	94%	83%	78%	72%	84%
25<30 years	97%	89%	86%	79%	90%
30+ years	100%	100%	100%	100%	100%

Table A10.4: Private Rented Sector: Proportion length of stay by EPC band

	A-C	D	E	F-G	All
<1year	48%	42%	40%	33%	43%
1<2 years	21%	20%	15%	14%	19%
2<3 years	10%	11%	12%	8%	11%
3<4 years	9%	7%	7%	6%	8%
4<5 years	5%	4%	3%	4%	4%
5<6 years	1%	4%	3%	2%	3%
6<7 years	1%	3%	2%	3%	2%
7<8 years	1%	1%	3%	2%	1%
8<9 years	1%	1%	2%	2%	1%
9<10 years	0%	1%	1%	2%	1%
10<15 years	2%	3%	6%	11%	4%
15<20 years	0%	1%	3%	2%	1%
20<25 years	0%	1%	1%	2%	1%
25<30 years	0%	0%	0%	2%	0%
30+ years	0%	1%	1%	5%	1%

Table A10.5: Private Rented Sector: Cumulative length of stay by EPC band

	A-C	D	E	F-G	All
<1year	48%	42%	40%	33%	43%
1<2 years	69%	62%	55%	47%	61%
2<3 years	79%	73%	66%	55%	72%
3<4 years	88%	80%	74%	61%	80%
4<5 years	93%	84%	77%	65%	84%
5<6 years	95%	89%	80%	68%	87%
6<7 years	96%	92%	82%	71%	89%
7<8 years	96%	93%	85%	73%	90%
8<9 years	97%	93%	87%	75%	91%
9<10 years	97%	95%	88%	77%	92%
10<15 years	100%	98%	94%	88%	97%
15<20 years	100%	98%	98%	91%	98%
20<25 years	100%	99%	99%	93%	99%
25<30 years	100%	99%	99%	95%	99%
30+ years	100%	100%	100%	100%	100%

17 APPENDIX 11: EXAMPLE ARCHETYPE

17.1 The base data for creating all of the individual archetypes was drawn directly from the SHCS data set, which was made available to the contractors for this research project.

17.2 The representative sample dwellings for each archetype were identified through the establishment of the typology and further segmentation as already set out in the main report.

17.3 Once the representative sample dwellings were identified, the base data for each archetype was extracted from the full SHCS data set and organised into a survey template that was created for this purpose. Effectively, a mail merge was performed to populate the template survey form with the necessary data for each archetype.

17.4 The survey data template for AT 1320130 is set out over the page in Figure A11.1. This archetype dwelling was a bungalow with an extension and a room in the roof.

17.5 To convert the SHCS data into a data set for the purposes of a full SAP assessment needed additional calculations.

17.6 The total floor area of the dwelling is the aggregation of the floor area of all levels of the dwelling:

- the ground level: 44m^2 (main dwelling) + 18m^2 (extension) [from SHCS data]:
- plus the upper level (which in this dwelling was the room in the roof area): 35m^2 [from SHCS data]
- = total floor area: 97m^2

17.7 As these were all internal measurements on this occasion, they did not need to be converted to internal dimensions – so 44m^2, 18m^2, and 35m^2 for the main dwelling, extension and room in the roof area floor area respectively were used.

17.8 The house volume was calculated by program from:

- ground level: ground level floor area: 62m^2 x storey height: 2.5m [from SHCS data]
- upper level: upper level floor area 35m^2 x 2.3m (2.05m [from SHCS data] + 0.25 [RdSAP convention])

17.9 Gross wall areas were calculated by multiplying the exposed perimeter for each part of the dwelling (main house and extension in this archetype) by the respective storey heights (both of which are collected by the SHCS)

- main house gross wall area: 21m [exposed perimeter] x 2.5m [storey height] = 52.5m^2

- extension gross wall area: 12m [exposed perimeter] x 2.5m [storey height] = 30.0m^2
- party wall area estimated: 3.26m [perimeter] x 2.5m [storey height] x 2 party walls = 16.3m^2

Figure A11.1: Base data extracted from SHCS

UPRN	24435431		Location: Angus		
archetype	Pre-1919-MidT/MTwP/EncEnd-s/stone-M.gas boiler-E-(1320130)				
Type of dwelling	mid terrace / not a flat				
Number of storeys	1	Rooms in Roof	2	Rooms in Basement	n/a
Year built:	1890	SHCS age:	pre 1919	NHER age	pre 1919
Mains services	E & gas			Electric meter	single
Conservatory / separation / heating		none / n/a / n/a			

	m^2	Int or ext	S. Ht	Exp Per	Ext Type	Age extension
GF or Lowest	44	internal	2.5	21		
+1	n/a	n/a	n/a	n/a		
+2	n/a	n/a	n/a	n/a		
+3	n/a	n/a	n/a	n/a		
Room in R	35	internal				
Ext 1	18	internal	2.5	12	#NA	1950-64
Ext 2	n/a	n/a	n/a	n/a	#NA	n/a

Heat Loss Floor

Floor construction / insulation	susTF / as built	
If flat	mid terrace / not a flat / #NA	
Ext 1 floor	solid / as built / #NA	
Ext 2 floor	n/a / #NA / #NA	
Zone 1 area	Number habitable rooms inc Kit	5

Heat Loss Walls

Main dwelling wall type	solid / stone / n/a / 450-750mm
Wall insulation	none / 0
% main wall	10
Alt wall type	n/a / #NA / #NA / #NA
Alt wall insulation	#NA / #NA
Ext 1 wall type	1950-64 / cavity / brick
Ext 1 wall insulation	none / 0
Ext 2 wall type	n/a / #NA / #NA
Ext 2 wall insulation	#NA / #NA
If Flat, wall exposure	not a flat / #NA
Type of corridor	#NA
Unheated corridor length	#NA

Heat loss roof

Main dwelling roof type / % cover	pitched / 8
If Flat, Type of heat loss roof	not a flat / #NA
L ins location and thickness	not applicable / none
Secondary roof type	mono
Ext 1 L ins location and thickness	n/a / none
Ext 2 L ins location and thickness	#NA / #NA

Glazing

Typical	yes
Frame	upvc
Glazing	DG pre 2003
Extent of DG	75% < 85%
Shutters?	none

Ventilation

Draught lobby: none	
If Flat: not a flat / no / #NA / #NA / #NA	
	Flueless gas fires n/a
Mechanical ventilation no	Extract Fans 0
Chimneys 3	
Flues 0	

Heating

Type / Fuel	gas boiler
Heat emitters	rads
Extent of heating	full

Hall	Kit	R1	R2	R3	R4	R5	Bath
entry	entry	entry	entry	first	first	no room	entry
[redacted]	kitchen only	living	public	bed	bed	#NA	bathroom
CHtg	CHtg	CHtg	CHtg	CHtg	CHtg	#NA	CHtg

Main heating system age	1998+
Boiler type:	standard / fan assisted / IDEAL MEXICO
Heat pump	n/a
Warm air	n/a
Electric wet	n/a
Gas room heaters	n/a
Solid fuel	n/a
ESH	n/a
P. Htg controls	prog & TRV
Secondary heating	electric room heater

Hot water

Source / fuel	gas / from P htg
HWC	normal (90-130 l) / sprayed / 30
C. Stat	yes

Renewables

S Panels or PV	yes / n/a / n/a
Private generation on site	no

CFLs

Any low energy lighting	up to 30%

17.10 The areas of the room in the roof components were obtained by entering the room in the roof area of 35m^2 [from SHCS data] into an RdSAP program and then turning on the extended data entry option:

- flat ceiling area 35m^2
- stud walls 18.6m^2
- sloping ceiling 18.6m^2
- gables 15.9m^2

17.11 The main house heat loss roof area (i.e. the area at the eaves) was calculated by subtracting the room in the roof area from the main house floor area:

- 44m^2 [from SHCS data] – 35m^2 [from SHCS data] = 9m^2

17.12 The extension heat loss roof area was taken as the extension floor area, so 18m^2

17.13 The heat loss ground floor areas of the main dwelling and extension were taken as the respective floor areas of these parts of the dwelling, as measured by the SHCS, so 44m^2 and 18m^2 respectively.

17.14 Window areas (which are not measured during SHCS, and are usually not measured during RdSAP surveys) were derived by entering the dwelling's dimensions, and its constructions and age details into a RdSAP program, and noting the calculated areas.

17.15 For this archetype, the calculated window areas were 10.25m^2 for main dwelling and 4.19m^2 for extension.

17.16 The SHCS for this archetype identified that between 75% and 85% of glazed area was double glazed with pre-2003 windows, so the midpoint of 80% was used to pro rata the window areas between the areas double glazed and areas single glazed in both parts of the dwelling, which produced:

- main dwelling: 8.2m^2 double glazed and 2.05m^2 single glazed
- extension: 3.35m^2 double glazed and 0.84m^2 single glazed

17.17 The area of doors was calculated from RdSAP defaults: 2 doors @ 1.85m^2 per door, so = 3.7m^2. One was assumed to be in the main dwelling; the other, in the extension.

17.18 By assigning windows and doors to specific parts of the dwelling, the SAP program subtracted these components automatically from the respective gross wall areas to produce net wall areas for each part of the dwelling

17.19 The U-values for the various fabric components of the dwelling were entered into a RdSAP program, noted, and then entered into the SAP program. The various Uvalues used for this sample archetype are set out on the Archetype Summary page below.

17.20 The main living area of the dwelling (that is, the area of the dwelling that SAP and RdSAP assume to be heated to the higher temperature standard of 21oC, compared to 18oC in the rest of the dwelling) was derived from the habitable room count in the SHCS data and the RdSAP defaults.

- number of habitable rooms inc kitchen: 5 [from SHCS data]
- SHCS room record kitchen description: kitchen only

- RdSAP habitable room count: 4 (as RdSAP explicitly does not include kitchens in the habitable room count)
- Table S11 of SAP (2012) default: 4 habitable rooms = 25% main living area
- main living area: 25% of total floor area of 97m^2 = 24.25m^2

17.21 The various ventilation factors were

- draught lobby: no porch in this dwelling [from SHCS data], so no
- number of chimneys / open fireplaces / large vents: 3 [from SHCS data]
- number of flues / small vents / air bricks: 0 [from SHCS data]
- number of extract fans: 0 [from SHCS data]
- number of flueless gas fires 0 [from SHCS data]
- presence of a mechanical ventilation system no [from SHCS data]

17.22 Draught proofing:

- 80% windows assumed to be draught proofed (all of the double glazed ones).
- 20% assumed to be not draught proofed (all of the single glazed ones).
- doors assumed to be not draught proofed.

17.23 The boiler in this dwelling was identified by the SHCS as a post-1998 standard, fan assisted Ideal Mexico mains gas boiler. As there are a large number of Ideal Mexico models of varying efficiencies in the PCDF, the boiler identification information on this occasion not sufficient to identify the specific boiler and its respective efficiency within the PCDF so SAP Table 4b default was used, which is 74%.

17.24 The SHCS found all habitable rooms were heated.

- Heating controls: programmer and TRVs [from SHCS data]
- Secondary heating: electric room heater [from SHCS data]
- Water heating: from primary heating [from SHCS data]
- Hot water cylinder details: normal 90-130 litres / 30mm spray foam [from SHCS data] (120 litres assumed)
- Cylinder thermostat: yes [from SHCS data]
- Conservatory: no conservatory [from SHCS data]
- Low energy lighting: up to 30% [from SHCS data]

17.25 The dwelling was identified as suitable for solar thermal panels and PVs, but none were installed already [from SHCS data]

17.26 Private generation on site: No [from SHCS data] (so, no wind turbine or other form of independent electricity generation

17.27 This data was entered into NES's Plan Assessor v6.1program, which produced the base case SAP worksheet for the respective archetype. The base case SAP worksheet for archetype 1320130 is shown over the next pages.

17.28 The delivered energy consumption figures, broken down by fuel use in the home, are set out in Table 9a of the worksheet between lines [219] and [238]; the calculated fuel costs, in Table 10a of the SAP worksheet; the CO_{2e} emission figures in Table 12a of the SAP worksheet; and the primary energy figures in Table 13a of the SAP worksheet

17.29 The SAP score and banding are set out in Table 11a of the SAP worksheet.

17.30 The Environmental Index score and banding are set out in Table 12a of the SAP worksheet

17.31 Each of the improvement measures were then modelled individually, and then combined into packages as necessary to achieve the respective SAP target scores.

17.32 This information was extracted for the base case, each of the individual measures, and the necessary packages, entered into a spreadsheet to calculate the various impacts of the measures and performance indicators.

17.33 The spreadsheet for each archetype is the source of the data published in the summary description of the archetype. The Summary description for archetype 1320130 is shown at the end of Chapter 4. All of the Summary descriptions are available on line at a Scottish Government-hosted web site.

Figure A11.2: Data for archetype 1320130 before measures in the SAP worksheet

SAP Worksheet
Design - Draft

NHER

This design submission has been carried out using Approved SAP software. It has been prepared from plans and specifications and may not reflect the property as constructed.

Assessor name	Dr Bill Sheldrick	Assessor number	29
Client	1320130	Last modified	19/11/2014
Address	base case REEPS, dalkeith, EH22 2QE		

1. Overall dwelling dimensions

		Area (m²)			Average storey height (m)			Volume (m³)	
Lowest occupied		62.00	(1a)	x	2.50	(2a)	=	155.00	(3a)
Roof room		35.00	(1n)	x	2.55	(2n)	=	89.25	(3n)
Total floor area	(1a) + (1b) + (1c) + (1d)...(1n) =	97.00	(4)						
Dwelling volume						(3a) + (3b) + (3c) + (3d)...(3n) =		244.25	(5)

2. Ventilation rate

				m³ per hour	
Number of chimneys		3	x 40 =	120	(6a)
Number of open flues		0	x 20 =	0	(6b)
Number of intermittent fans		0	x 10 =	0	(7a)
Number of passive vents		0	x 10 =	0	(7b)
Number of flueless gas fires		0	x 40 =	0	(7c)
				Air changes per hour	
Infiltration due to chimneys, flues, fans, PSVs	(6a) + (6b) + (7a) + (7b) + (7c) =	120	÷ (5) =	0.49	(8)

If a pressurisation test has been carried out or is intended, proceed to (17), otherwise continue from (9) to (16)

Number of storeys in the dwelling		2		(9)
Additional infiltration			0.10	(10)
Structural infiltration: 0.25 for steel or timber frame or 0.35 for masonry construction			0.35	(11)
If suspended wooden ground floor, enter 0.2 (unsealed) or 0.1 (sealed), else enter 0			0.20	(12)
If no draught lobby, enter 0.05, else enter 0			0.05	(13)
Percentage of windows and doors draught proofed		68.00		(14)
Window infiltration	0.25 - [0.2 x (14) ÷ 100] =		0.11	(15)
Infiltration rate	(8) + (10) + (11) + (12) + (13) + (15) =		1.31	(16)
If based on air permeability value, then (18) = [(17) ÷ 20] + (8), otherwise (18) = (16)			1.31	(18)
Number of sides on which the dwelling is sheltered			2	(19)
Shelter factor	1 - [0.075 x (19)] =		0.85	(20)
Infiltration rate incorporating shelter factor	(18) x (20) =		1.11	(21)

Infiltration rate modified for monthly wind speed:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Monthly average wind speed from Table U2	5.10	5.00	4.90	4.40	4.30	3.80	3.80	3.70	4.00	4.30	4.50	4.70	(22)
Wind factor (22)m ÷ 4	1.28	1.25	1.23	1.10	1.08	0.95	0.95	0.93	1.00	1.08	1.13	1.18	(22a)

Adjusted infiltration rate (allowing for shelter and wind factor) (21) x (22a)m

1.41	1.39	1.36	1.22	1.19	1.05	1.05	1.03	1.11	1.19	1.25	1.30	(22b)

Calculate effective air change rate for the applicable case:

If mechanical ventilation: air change rate through system	N/A	(23a)
If balanced with heat recovery: efficiency in % allowing for in-use factor from Table 4h	N/A	(23c)

d) natural ventilation or whole house positive input ventilation from loft

1.41	1.39	1.36	1.22	1.19	1.05	1.05	1.03	1.11	1.19	1.25	1.30	(24d)

Effective air change rate - enter (24a) or (24b) or (24c) or (24d) in (25)

1.41	1.39	1.36	1.22	1.19	1.05	1.05	1.03	1.11	1.19	1.25	1.30	(25)

3. Heat losses and heat loss parameter

Element	Gross area, m²	Openings m²	Net area A, m²		U-value W/m²K		A x U W/K	κ-value, kJ/m².K	A x κ, kJ/K	
Window			2.05	x	4.03	=	8.26			(27)
Door			3.70	x	3.00	=	11.10			(26)
Window			12.39	x	2.52	=	31.20			(27)
Ground floor			44.00	x	0.68	=	29.92			(28a)
Ground floor			18.00	x	0.82	=	14.76			(28a)
External wall			23.96	x	1.60	=	38.34			(29a)
External wall			56.30	x	1.41	=	79.38			(29a)
External wall			18.60	x	2.30	=	42.78			(29a)
Party wall			16.30	x	0.00	=	0.00			(32)
Roof			80.60	x	2.30	=	185.38			(30)
Total area of external elements ∑A, m²			259.60							(31)

Fabric heat loss, W/K = ∑(A × U)	(26)...(30) + (32) =	441.11	(33)
Heat capacity Cm = ∑(A x κ)	(28)...(30) + (32) + (32a)...(32e) =	N/A	(34)
Thermal mass parameter (TMP) in kJ/m²K		250.00	(35)
Thermal bridges: ∑(L x Ψ) calculated using Appendix K		38.94	(36)
Total fabric heat loss	(33) + (36) =	480.05	(37)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Ventilation heat loss calculated monthly 0.33 x (25)m x (5)	114.02	111.79	109.55	98.37	96.14	84.96	84.96	82.72	89.43	96.14	100.61	105.08	(38)
Heat transfer coefficient, W/K (37)m + (38)m	594.07	591.84	589.60	578.42	576.19	565.01	565.01	562.77	569.48	576.19	580.66	585.13	
Average = ∑(39)1...12/12 =												577.86	(39)
Heat loss parameter (HLP), W/m²K (39)m ÷ (4)	6.12	6.10	6.08	5.96	5.94	5.82	5.82	5.80	5.87	5.94	5.99	6.03	
Average = ∑(40)1...12/12 =												5.96	(40)
Number of days in month (Table 1a)	31.00	28.00	31.00	30.00	31.00	30.00	31.00	31.00	30.00	31.00	30.00	31.00	(40)

4. Water heating energy requirement

Assumed occupancy, N	2.71	(42)
Annual average hot water usage in litres per day Vd,average = (25 x N) + 36	103.75	(43)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Hot water usage in litres per day for each month Vd,m = factor from Table 1c x (43)	114.12	109.97	105.82	101.67	97.52	93.37	93.37	97.52	101.67	105.82	109.97	114.12	
∑(44)1...12 =												1244.99	(44)
Energy content of hot water used = 4.18 x Vd,m x nm x Tm/3600 kWh/month (see Tables 1b, 1c 1d)	169.24	148.02	152.74	133.17	127.78	110.26	102.17	117.24	118.65	138.27	150.93	163.90	

∑(45)1...12 = 1632.38 (45)

Distribution loss 0.15 x (45)m

25.39	22.20	22.91	19.97	19.17	16.54	15.33	17.59	17.80	20.74	22.64	24.59	(46)

Storage volume (litres) including any solar or WWHRS storage within same vessel 120.00 (47)

Water storage loss:

b) Manufacturer's declared loss factor is not known

Hot water storage loss factor from Table 2 (kWh/litre/day)	0.02	(51)
Volume factor from Table 2a	1.00	(52)
Temperature factor from Table 2b	0.60	(53)
Energy lost from water storage (kWh/day) (47) x (51) x (52) x (53)	1.52	(54)
Enter (50) or (54) in (55)	1.52	(55)

Water storage loss calculated for each month (55) x (41)m

47.27	42.69	47.27	45.74	47.27	45.74	47.27	47.27	45.74	47.27	45.74	47.27	(56)

If the vessel contains dedicated solar storage or dedicated WWHRS (56)m x [(47) - Vs] ÷ (47), else (56)

47.27	42.69	47.27	45.74	47.27	45.74	47.27	47.27	45.74	47.27	45.74	47.27	(57)

Primary circuit loss for each month from Table 3

64.58	58.33	64.58	62.50	64.58	41.92	43.31	43.31	41.92	64.58	62.50	64.58	(59)

Combi loss for each month from Table 3a, 3b or 3c

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	(61)

Total heat required for water heating calculated for each month 0.85 x (45)m + (46)m + (57)m + (59)m + (61)m

281.09	249.04	264.59	241.40	239.62	197.92	192.75	207.82	206.30	250.11	259.17	275.75	(62)

Solar DHW input calculated using Appendix G or Appendix H

0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	(63)

Output from water heater for each month (kWh/month) (62)m + (63)m

281.09	249.04	264.59	241.40	239.62	197.92	192.75	207.82	206.30	250.11	259.17	275.75

∑(64)1...12 = 2865.57 (64)

Heat gains from water heating (kWh/month) 0.25 × [0.85 × (45)m + (61)m] + 0.8 × [(46)m + (57)m + (59)m]

145.75	130.03	140.26	130.87	131.96	106.79	106.44	111.45	109.58	135.45	136.77	143.97	(65)

5. Internal gains

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Metabolic gains (Table 5)													
	162.60	162.60	162.60	162.60	162.60	162.60	162.60	162.60	162.60	162.60	162.60	162.60	(66)
Lighting gains (calculated in Appendix L, equation L9 or L9a), also see Table 5													
	100.48	89.24	72.58	54.94	41.07	34.67	37.47	48.70	65.37	83.00	96.87	103.27	(67)
Appliance gains (calculated in Appendix L, equation L13 or L13a), also see Table 5													
	375.20	379.09	369.28	348.40	322.03	297.25	280.69	276.80	286.61	307.50	333.87	358.65	(68)
Cooking gains (calculated in Appendix L, equation L15 or L15a), also see Table 5													
	53.97	53.97	53.97	53.97	53.97	53.97	53.97	53.97	53.97	53.97	53.97	53.97	(69)
Pump and fan gains (Table 5a)													
	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	(70)
Losses e.g. evaporation (Table 5)													
	-108.40	-108.40	-108.40	-108.40	-108.40	-108.40	-108.40	-108.40	-108.40	-108.40	-108.40	-108.40	(71)
Water heating gains (Table 5)													
	195.90	193.50	188.53	181.76	177.37	148.32	143.06	149.79	152.19	182.06	189.96	193.51	(72)
Total internal gains (66)m + (67)m + (68)m + (69)m + (70)m + (71)m + (72)m													
	789.74	780.01	748.55	703.27	658.64	598.41	579.39	593.47	622.34	690.72	738.87	773.60	(73)

6. Solar gains

	Access factor Table 6d		Area m²		Solar flux W/m²		g specific data or Table 6b		FF specific data or Table 6c		Gains W	
East	0.77	x	2.05	x	19.64	x 0.9 x	0.85	x	0.70	=	16.60	(76)
East	0.77	x	12.39	x	19.64	x 0.9 x	0.76	x	0.70	=	89.71	(76)

Solar gains in watts ∑(74)m...(82)m

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
106.32	207.98	342.51	499.53	612.19	626.69	596.63	512.50	398.35	246.78	132.56	87.43	(83)

Total gains - internal and solar (73)m + (83)m

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
896.06	987.99	1091.06	1202.80	1270.83	1225.10	1176.02	1105.96	1020.69	937.51	871.43	861.03	(84)

7. Mean internal temperature (heating season)

Temperature during heating periods in the living area from Table 9, Th1(°C) 21.00 (85)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Utilisation factor for gains for living area n1,m (see Table 9a)	0.99	0.98	0.98	0.96	0.94	0.90	0.84	0.86	0.93	0.97	0.98	0.99	(86)
Mean internal temp of living area T1 (steps 3 to 7 in Table 9c)	16.47	16.70	17.23	18.02	18.87	19.70	20.23	20.15	19.47	18.40	17.33	16.46	(87)
Temperature during heating periods in the rest of dwelling from Table 9, Th2(°C)	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	(88)
Utilisation factor for gains for rest of dwelling n2,m	0.98	0.98	0.97	0.94	0.89	0.77	0.51	0.58	0.85	0.95	0.97	0.98	(89)
Mean internal temperature in the rest of dwelling T2 (follow steps 3 to 7 in Table 9c)	14.36	14.59	15.12	15.90	16.73	17.50	17.90	17.87	17.30	16.27	15.21	14.34	(90)

Living area fraction — Living area ÷ (4) = 0.25 (91)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean internal temperature for the whole dwelling fLA x T1 +(1 - fLA) x T2	14.89	15.12	15.65	16.43	17.26	18.05	18.48	18.44	17.84	16.81	15.74	14.87	(92)
Apply adjustment to the mean internal temperature from Table 4e where appropriate	14.89	15.12	15.65	16.43	17.26	18.05	18.48	18.44	17.84	16.81	15.74	14.87	(93)

8. Space heating requirement

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Utilisation factor for gains, ηm	0.97	0.97	0.95	0.92	0.87	0.78	0.61	0.65	0.84	0.93	0.96	0.97	(94)
Useful gains, ηmGm, W (94)m x (84)m	870.86	953.61	1038.28	1111.66	1110.71	952.96	717.30	723.42	857.26	872.05	838.90	838.56	(95)
Monthly average external temperature from Table U1	4.30	4.90	6.50	8.90	11.70	14.60	16.60	16.40	14.10	10.60	7.10	4.20	(96)
Heat loss rate for mean internal temperature, Lm, W [(39)m x [(93)m - (96)m]	6291.96	6048.17	5392.67	4353.94	3204.98	1948.67	1064.86	1146.52	2132.19	3576.21	5018.74	6244.24	(97)
Space heating requirement, kWh/month 0.024 x [(97)m - (95)m] x (41)m	4033.30	3423.55	3239.67	2334.45	1558.14	0.00	0.00	0.00	0.00	2011.90	3009.49	4021.83	

∑(98)1...5, 10...12 = 23632.31 (98)

Space heating requirement kWh/m²/year — (98) ÷ (4) 243.63 (99)

9a. Energy requirements - individual heating systems including micro-CHP

Space heating

Fraction of space heat from secondary/supplementary system (table 11) 0.10 (201)

Fraction of space heat from main system(s) — 1 - (201) = 0.90 (202)

Fraction of space heat from main system 2		0.00	(202)
Fraction of total space heat from main system 1	(202) x [1- (203)] =	0.90	(204)
Fraction of total space heat from main system 2	(202) x (203) =	0.00	(205)
Efficiency of main system 1 (%)		69.00	(206)
Efficiency of secondary/supplementary system (%)		100.00	(208)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Space heating fuel (main system 1), kWh/month	5260.82	4465.50	4225.65	3044.93	2032.35	0.00	0.00	0.00	0.00	2624.22	3925.42	5245.86	
∑(211)1...5, 10...12 =												30824.75	(211)
Space heating fuel (secondary), kWh/month	403.33	342.35	323.97	233.44	155.81	0.00	0.00	0.00	0.00	201.19	300.95	402.18	
∑(215)1...5, 10...12 =												2363.23	(215)
Water heating													
Efficiency of water heater	68.17	68.14	68.04	67.82	67.33	59.00	59.00	59.00	59.00	67.61	67.99	68.18	(217)
Water heating fuel, kWh/month	412.34	365.51	388.87	355.97	355.87	335.45	326.70	352.24	349.67	369.94	381.17	404.43	
∑(219a)1...12 =												4398.15	(219)

Annual totals

Space heating fuel - main system 1			30824.75	
Space heating fuel - secondary			2363.23	
Water heating fuel			4398.15	
Electricity for pumps, fans and electric keep-hot (Table 4f)				
central heating pump or water pump within warm air heating unit	156.00			(230c)
boiler flue fan	45.00			(230e)
Total electricity for the above, kWh/year			201.00	(231)
Electricity for lighting (Appendix L)			709.77	(232)
Total delivered energy for all uses		(211)...(221) + (231) + (232)...(237b) =	38496.90	(238)

10a. Fuel costs - individual heating systems including micro-CHP

	Fuel kWh/year		Fuel price		Fuel cost £/year	
Space heating - main system 1	30824.75	x	3.48	x 0.01 =	1072.70	(240)
Space heating - secondary	2363.23	x	13.19	x 0.01 =	311.71	(242)
Water heating	4398.15	x	3.48	x 0.01 =	153.06	(247)
Pumps and fans	201.00	x	13.19	x 0.01 =	26.51	(249)
Electricity for lighting	709.77	x	13.19	x 0.01 =	93.62	(250)
Additional standing charges					120.00	(251)
Total energy cost				(240)...(242) + (245)...(254) =	1777.60	(255)

11a. SAP rating - individual heating systems including micro-CHP

Energy cost deflator (Table 12)	0.42	(256)
Energy cost factor (ECF)	5.26	(257)
SAP value	29.78	
SAP rating (section 13)	30	(258)
SAP band	F	

12a. CO_2 emissions - individual heating systems including micro-CHP

	Energy kWh/year		Emission factor kg CO_2/kWh		Emissions kg CO_2/year	
Space heating - main system 1	30824.75	x	0.22	=	6658.15	(261)
Space heating - secondary	2363.23	x	0.52	=	1226.52	(263)
Water heating	4398.15	x	0.22	=	950.00	(264)
Space and water heating			(261) + (262) + (263) + (264) =		8834.66	(265)
Pumps and fans	201.00	x	0.52	=	104.32	(267)
Electricity for lighting	709.77	x	0.52	=	368.37	(268)
Total CO_2, kg/year			(265)...(271) =		9307.35	(272)
Dwelling CO_2 emission rate			(272) ÷ (4) =		95.95	(273)
EI value					27.43	
EI rating (section 14)					27	(274)
EI band					F	

13a. Primary energy - individual heating systems including micro-CHP

	Energy kWh/year		Primary factor		Primary Energy kWh/year	
Space heating - main system 1	30824.75	x	1.22	=	37606.20	(261)
Space heating - secondary	2363.23	x	3.07	=	7255.12	(263)
Water heating	4398.15	x	1.22	=	5365.74	(264)
Space and water heating			(261) + (262) + (263) + (264) =		50227.06	(265)
Pumps and fans	201.00	x	3.07	=	617.07	(267)
Electricity for lighting	709.77	x	3.07	=	2179.00	(268)
Primary energy kWh/year					53023.13	(272)
Dwelling primary energy rate kWh/m2/year					546.63	(273)

18 APPENDIX 12: RESEARCH ADVISORY GROUP (RAG) MEMBERSHIP

18.1 The Research Advisory Group for the research project comprised:

- **Scottish Government:**
  - Adam Krawczyk (Chair), Senior Statistician, Communities Analytical Services
  - Valerie Sneddon, REEPS Policy Team
  - Katie Chan, REEPS Policy Team
  - Jamie Robertson, Statistician, Communities Analytical Services
  - Oscar Guinea/Bruce Teubes, Economists, Communities Analytical Services
  - Fraser Walsh, Building Standards
- **Historic Scotland:**
  - Roger Curtis, Technical Research Manager:
- **External members:**
  - Elizabeth Leighton, Existing Homes Alliance (EXHA) Scotland
  - Kevin Christie, Aberdeen City Council
  - Victor Burnett, Scottish Land and Estates

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