Energy Efficiency Standard for Social Housing: Peer Review

natural scotland
SCOTTISH GOVERNMENT

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This report is published electronically to limit the use of paper, but photocopies will be provided on request to Housing Sustainability and Innovative Funding Division

Contents

Reference Table: Guide to Retrofit Examples

Property Ref *	Description
A-1	Pre 1919 solid wall dwelling ground floor
A-2	Pre 1919 solid wall dwelling mid floor
A-3	Pre 1919 solid wall dwelling top floor
B-4	1930-49 mid-floor flat
B-5	1930-49 mid-terrace
B-6	1930-49 semi-detached
C-7	1930-49 four-in-a-block lower
C-8	1930-49 four-in-a-block upper
D-9	1950-64 post war mid-floor flat
D-10	1950-64 post war mid-terrace
D-11	1950-64 post war semi-detached
E-12	1976-83 mid-floor flat
E-13	1976-83 mid-terrace
E-14	1976-83 semi-detached
F-15	1984-91 mid-floor flat
F-16	1984-91 mid-terrace
F-17	1984-91 semi-detached
G-18	1992-98 mid-floor flat
G-19	1992-98 mid-terrace
G-20	1992-98 semi-detached
H-21	1999-2007 mid-floor flat
H-22	1999-2007 mid-terrace
H-23	1999-2007 semi-detached
HTT-1	Pre-1919 tenement flat ground floor, gable end
HTT-2	Pre-1919 tenement flat top floor, gable end, partial flat roof
HTT-3	1950-64 multi-storey flat ground floor, gable end
HTT-4	1950-64 multi-storey flat Mid-floor, gable end
HTT-5	1950-64 external deck access flat ground floor, gable end
HTT-6	1950-64 external deck access flat mid-floor, gable end
HTT-7	1950-64 No Fines concrete flat - ground floor, gable end
HTT-8	1950-64 No Fines concrete flat - top floor, gable end
HTT-9	Swedish timber house, semi-detached
HTT-10	1950-1982 timber house , semi-detached
HTT-11	System-built concrete house, semi-detached
HTT-12	BISF steel frame house, semi-detached
**** Please note that an "E" after that reference number denotes electric heating and a "G" denotes mains gas heating.***	

Glossary

DECC	Department of Energy and Climate Change	
CERO	Carbon Emissions Reduction Obligation	Part of the ECO focused on solid wall insulation and hard-to-treat cavity wall insulation measures
ECO	Energy Companies Obligation	Obligation on energy companies to fund energy efficiency measures
EE	Energy Efficiency Rating (or SAP rating)	Dwelling energy costs associated with space & water heating, ventilation and lighting.
	EE Band	Band between G (poor) and A (Good) based on the SAP score
EESSH	Energy Efficiency Standard for Social Housing	Proposed standard related to energy efficiency
EI	Environmental Impact Rating	Dwelling carbon dioxide (CO_2) emissions associated with space & water heating, ventilation and lighting.
	EI band	Band between G (poor) and A (Good) based on the SAP score
EPC	Energy Performance Certificate	Provides an illustration of the energy efficiency of a building based on standard assertions for occupation and use.
FIT	Feed in Tariff	Payment for renewable electricity generation paid by energy companies
HTT	Harder-to-treat	A property where more complicated or expensive measures are needed
In-situ	Onsite testing	Used to determine actual rather estimated U-values
NHER	National Home Energy Rating	Variant of RdSAP with additional variables
RdSAP	Reduced data Standard Assessment Procedure	RdSAP was introduced in 2005 as a lower cost method of assessing the performance of existing dwellings to produce an EPC.
RHI	Renewable Heat Incentive	Subsidy for renewable heat generation paid by UK government
RSL	Registered Social Landlord	Housing Associations and Co-ops
SAP	Standard Assessment Procedure	The methodology used by the Department of Energy & Climate Change (DECC) to assess and compare the energy and environmental performance of dwellings
SHQS	Scottish Housing Quality Standard	A minimum standard for social housing to be met by 2015 which also includes an energy efficiency criterion
SPONS		Reference for prices and costs of measures (for example, used by Quantity Surveyors).
SWI	Solid Wall Insulation	Either external or internal insulation
U-value		Is a measure of heat loss by conduction through the building fabric and is measured in W/m^2K. The lower the value, the more resistant the fabric will be to heat loss.

1 Executive Summary

The key aim of this Peer Review is to scrutinise the Example Dwellings (formerly known as the "Case Studies") in the Energy Efficiency Standard for Social Housing (EESSH) consultation document (issued June 2012), for the purpose of validation, and ensuring they provide clear, consistent and useful advice for social landlords regarding meeting an achievable standard. The setting of an EESSH is in line with the Scottish Government‟s climate change targets and the needs of tenants.

To do this, Heriot-Watt University considered the evidence base behind key assumptions underpinning the standard and the examples demonstrating how it could be met. Changeworks validated the modelling using the most up-to-date versions of the RdSAP software available. Changeworks also provided commentary based on retrofit work with housing associations and local authorities. David Adamson and Partners provided validation in relation to the costs of measures drawing on Quantity Surveying work for a wide range of social landlords. The report annex provides detailed commentary and validation for each of the examples used to inform the standard.

It is 23 years since the baseline for climate change targets was drawn up. In this era less data was collected than would be the case today. For instance the first Scottish House Condition Survey was carried out in 1991 and the methodology and coverage has expanded since then. Based on the available evidence, the baseline assumptions withstood scrutiny and were credible. However, it was noted that there could be alternate assumptions in terms of the baseline inputs for hot water tank insulation, loft insulation depth and in some cases, numbers of open chimneys. Alternative assumptions were assessed and are discussed both in the report and in further depth in **The Report Annex: Review and Validation of Consultation Case Studies (now Example Dwellings)**. When these variables were tested the results were not significant enough to invalidate the assumption used in the consultation. It was also noted that standards for loft insulation in the Scottish Housing Quality Standard (SHQS) were less than building standards and, in most but not all cases, installers will have installed 200-250mm rather than the minimum 100mm currently required by SHQS. Overall, none of these issues would have an impact on the path to complying with either the SHQS by 2015 or EESSH by 2020.

The original selection of 23 retrofit example dwellings fitted well with the profile of the Scottish social housing stock, although there were areas (e.g. flats) where coverage needed to be extended. These have been addressed through the provision of 12 further examples focused on harder-to-treat property types to illustrate strategies that show how the standard can be achieved. However, it must also be stressed that all examples within the EESSH are illustrative rather than prescriptive: landlords are free to meet the standard in whatever way they feel best meets the needs of their own stock and tenants. Aside from older tenements and modern system built housing with solid walls, it was reasonably practical to meet the standard without the need for „advanced" measures. In the case of these harder-to-treat properties it is argued that external solid wall insulation should be classed as a „further measure" applicable to the 2020 period, rather than an „advanced measure" noted for meeting targets along the road to 2050. External wall insulation is an established technology and can attract funding from the Carbon Emission Reduction Obligation (CERO).

Other notable observations were that:

- Some communal measures are inadequately recognised by RdSAP; this could discourage landlords from implementing measures that are not always fully recognised as contributing towards the EESSH, but might still deliver benefits to tenants;
- Certain improvement measures are likely to prove challenging to install across the board. A key example is external and internal solid wall insulation, where barriers may relate to planning restrictions, multi-tenure issues, tenant disruption, tenant refusal and/or insufficient subsidy to offset high capital costs;
- Remodelling the consultation draft examples with a more up to date version of RdSAP (2009 v9.90) as opposed to RdSAP (2005 v9.83) resulted in a shift in the Energy Efficiency (EE) and Environmental Impact (EI) rating of a number of properties. This was almost entirely down to evolutions in the software and alterations to the base assumptions;
- Utilising the expanded functionality in the latest version of RdSAP 2009 v9.91 such as specifying property specific rather than default U-values will boost the modelled baseline and post-improvement ratings of some properties but will have a converse impact elsewhere. It is recommended that the Scottish Government considers the evidence base that social landlords can draw on when deviating from the software defaults;
- Off-gas properties may face greater challenges as they are likely to have lower energy efficiency and environmental impact ratings, reflecting the higher costs and carbon content of alternative fuels. The proposed standard anticipates this issue (with a lower standard for electrically heated properties) so any issues will be confined to particularly poorly performing properties that cannot achieve the desired energy efficiency rating via cost effective fabric improvements alone.
- A new version of RdSAP was launched after the publication of the consultation document; the two versions were compared as part of this Peer Review and the enhanced facilities of the newer version tested. This established that a basic use of the newer version is unlikely to result in any significant changes over the previous version, and both have limitations that could affect the EE and/or EI ratings that some property types could achieve;
- Upgrade measure costs were found to be broadly representative. Microgeneration system costs were queried, however these are subject to more change over time, particularly as funding changes and incentives are likely to play a part both in unit costs and uptake by landlords;
- There is limited historic evidence showing the application of some improvement measures (e.g. floor insulation) used in the retrofit examples;

- Internal solid wall insulation presents major challenges to widespread uptake in the short to medium term. It should be noted as an „advanced measure";
- Additional costs to cover issues such as decants, staff negotiation time and specialist upgrade measures are likely to be an issue for some landlords;
- Achieving both high EE and EI standards is likely to be difficult for some off-gas properties;
- For certain microgeneration systems, landlords are likely to require investment of additional time and resources to ensure that tenants are able to use them effectively and realise the savings predicted;
- The changing funding arena will inevitably influence landlords" investment decisions. While the impact of the Green Deal in social housing remains to be seen, the ECO and the pending domestic Renewable Heat Incentive (RHI) are both likely to play a key role;
- Legal issues, particularly those surrounding multi-tenure properties, will affect the ability of some landlords to upgrade their stock cost-effectively.

Whilst it was possible to cost the delivery up to 2020, the authors have some concerns about how accurate this calculation can be given the high number of uncertainties and assumptions that underpin it. As a starting point, the 35 retrofit examples dwellings offer a good profile but this can never really address the variations in the stock. This calculation is therefore provided as a guide rather than a definitive assessment. It is broadly in line with similar recent studies. The actual costs to social landlords will reflect prices at the time of installation and levels of support from mechanisms such as ECO.

2 Introduction

The Scottish Government appointed Changeworks to lead a Peer Review of the energy performance information provided in the Energy Efficiency Standard for Social Housing consultation document (issued June 2012). Changeworks led this process with support from David Adamson Chartered Surveyors and the Urban Energy Research Group at Heriot-Watt University.

The Peer Review had six objectives, as follows:

1. Check and provide commentary on the assumptions used for the 1990 baseline, the Scottish Housing Quality Standard and the further and advanced measures;

2. Reproduce the retrofit examples referred to in the consultation document using the most up-to-date version of RdSAP 2009 (v9.90) available;

3. Produce (a maximum of 12) similar retrofit examples for a range of representative expensive/harder-to-treat dwelling types modelled using RdSAP 2009 (v9.91);

4. Provide commentary on how communal improvements can be adequately accounted for in the approach;

5. Provide an indicative upgrade cost for meeting the standard for each retrofit example along with indicative energy savings for the tenant and carbon abatement, as well as aggregating these across the Scottish social housing stock to give aggregate upgrade costs, energy savings and carbon abatement for the standard as a whole;

6. Provide commentary on the technical, financial and organisational reasonableness and risks to landlords of meeting the proposed standards as set out in the consultation document.

Each of these objectives is addressed in the relevant chapter of this document, followed by conclusions for consideration and a set of recommendations to validate and refine the standard.

This Peer Review is intended for publication as a supporting document alongside the finalised Energy Efficiency Standard for Social Housing (EESSH). The report has been written for the Scottish Government; however, social housing providers may also find the content helpful in understanding their requirements and how the standard has been developed. The EESSH consultation document attracted a large number of responses. These are available online and may also be of interest to social landlords.

2.1 RdSAP methodology

The basis of the EESSH is RdSAP, the same assessment methodology that underpins Energy Performance Certificates (EPCs). RdSAP stands for Reduced data Standard Assessment Procedure. As the name suggests, therefore, it is a pared-down version of the full SAP. RdSAP is used to calculate energy efficiency and environmental performance ratings, and uses a combination of manually entered data sets and assumptions to estimate a property"s performance. RdSAP is updated periodically to take account of new evidence and developments in both the software and its assumptions (e.g. default U-values, building specifications, costs and CO_2 factors etc.) For simplicity, both RdSAP 2009 v9.90 and RdSAP 2009 v9.91 use a series of defaults (best fits) for many factors such as walls. However, the latest version also provides scope for a more skilled energy assessor to specify values based on documented specifications, where they are available. This will be relevant to social landlords with non-standard properties that do not equate well with RdSAP defaults. This enhanced functionality is discussed in section 5.2.

General information on this tool is widely available[1]. However a more detailed awareness of its functions and assumptions is helpful in understanding how it predicts the energy efficiency, environmental impacts and energy costs of housing. This Peer Review identifies and explains a number of aspects of RdSAP that affect its performance predictions. Previous and current versions are compared; assumptions pertaining to energy use and property dimensions are highlighted; and its default specifications and values are assessed. The function of this Peer Review is not to scrutinise these issues in exhaustive detail; more details can be found in other research reports and publications[2]. It is important, however, to recognise the effect these issues can have on social landlords" ability to meet the proposed ratings within the EESSH.

2.2 Environmental Impact and Energy Efficiency ratings

Throughout the document, reference is made to various standards, ratings and sets of improvement measures. For clarification, „EE" and „EI" ratings refer to „energy efficiency" (EE) and „environmental impact" (EI) provided by RdSAP (the assessment methodology), with minimum bands proposed for each by the EESSH. It is important for landlords to be aware that the two ratings are not always closely linked, and it will be easier for some properties to meet one rating than the other.

2.3 Further and advanced measures

Reference is made in this document to „further" and „advanced measures": this refers to groups of improvement measures used as examples in the consultation document. „Further" measures are those used to illustrate improvements that may be applied to take a property from the 2015 SHQS to the 2020 EESSH; „advanced"

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[1] E.g. http://www.decc.gov.uk/en/content/cms/emissions/sap/sap.aspx

[2] E.g. Historic Scotland Technical Papers (http://conservation.historic-scotland.gov.uk/home.htm); SPAB energy efficiency research (http://www.spab.org.uk/advice/energy-efficiency/)

measures are those used to illustrate improvements that may be applied to improve a property beyond the 2020 EESSH.

2.4 The Scottish Housing Quality Standard

The Scottish Housing Quality Standard (SHQS) is based on a minimum NHER/SAP score and the presence of prescribed elements. These are outlined in Appendix B.

2.5 The Energy Efficiency Standard for Social Housing

The new standard is based on the minimum energy efficiency rating specific to different types of property which takes account of the fuel used for space heating. The standards outlined in the consultation document are in Appendix C.

3 Commentary on Assumptions

Each retrofit example in the EESSH consultation document uses a baseline energy efficiency standard from 1990. Three improvement stages are used to consider the cumulative application of efficiency measures to improve the energy performance of the dwelling („2015 Scottish Housing Quality Standard" (SHQS), „2020 Further Measures", and „2050 Advanced Measures").

The purpose of these retrofit examples is to illustrate possible routes by which social landlords can achieve compliance with the standard through application of typical measures. It is important to note that the suggested measures do not represent a definitive list, and will not be suitable for all dwellings; the examples do, however, cover a broad range of social housing types and can help social landlords to identify an approach suitable for their own stock. It should be noted throughout that social landlords can achieve the EESSH using any measures that they consider appropriate.

The first Peer Review objective was to consider the assumptions used in these retrofit examples, determine whether they provide a sufficient representation of Scotland"s social housing stock, and identify any significant building types not currently represented by the initial 23 examples. This process required a comparison of the assumption data against historic information, previous building standards and the default SAP and RdSAP assumptions. Additional commentary is provided, discussing the practical application of the proposed measures based on the experiences of previous projects.

3.1 Description of the social housing stock

3.1.1 Fuel mix

The retrofit examples consider properties which feature gas and electric heating systems. Whilst information is not available describing Scotland"s heating energy consumption independently prior to 2005, UK-wide data shows there has been a significant shift in the fuel mix for domestic energy since 1990: then, 8% was provided by coal, 63% by gas and 18% electricity; by 2010 this had changed to 1% coal, 66% natural gas and 21% electricity[3].

For the purposes of the EESSH, it should be noted that while solid mineral fuel only accounts for 1% of the domestic fuel mix, it will be harder to bring properties heated by this fuel up to similar ratings set for gas and electrically heated dwellings (without changing fuel type). This is because RdSAP allocates a very poor environmental

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[3] „Energy Use in the Home – Measuring and Analysing Domestic Energy Use and Energy Efficiency in Scotland", The Scottish Government, August 2012

impact rating to such fuels. It should also be noted that biomass may be considered as a solid fuel and while the calculated Environmental Impact rating is very good the Energy Efficiency rating may be much poorer, as this rating takes account of the fuel cost.

3.1.2 Building stock composition

The draft EESSH outlines 23 retrofit examples representative of the most common building types identified within the social housing stock. The retrofit technologies discussed in this report are therefore considered applicable, and relevant, to a large proportion of this stock. The retrofit examples aim to demonstrate the impact of typical energy efficiency measures; however, it is important to bear in mind that the approach applied to actual dwellings will vary from building to building, subject to their individual features and characteristics. These retrofit examples are not intended as prescriptive routes to compliance across the stock, but can be used as a reference point by social landlords, particularly in relation to the target ratings outlined by the SHQS and EESSH.

In reviewing the suitability of these example dwellings, it is important to understand which aspects of the social housing stock they represent. An analysis of this data was used to inform the selection of additional example dwellings (see Section 5) to address areas not currently represented.

Appendix A: Housing Stock Summary summarises the composition of the entire Scottish domestic building stock, detailing the number of properties for each building type and period of construction. Consideration of the mean CO_2 emissions relative to these categories shows that in most cases, the older stock has higher emissions[4]. The 23 retrofit examples were cross-referenced against the categories listed in Appendix A, highlighting a number of anomalies:

- None of the examples describe detached properties (although this could be said to be a valid exclusion, as these represent less than 1% of the social housing stock[5])

- No pre-1919 houses are included, which is justified as the majority of social pre-1919 dwellings owned by social landlords stock are tenements (Figure 1 and Figure 2)

- With the exception of group C (four-in-a-block flats constructed between 1920 and 1949) the retrofit examples do not consider any „other flats". Figure 2 shows a significant proportion of high-rise dwellings, constructed between 1965 and 1982. These properties are often unable to accommodate low-cost measures such as cavity and loft insulation and thus may be deemed „harder-

[4] „Scottish House Condition Survey – Key Findings 2010", The Scottish Government, November 2011

[5] „Energy Use in the Home – Measuring and Analysing Domestic Energy Use and Energy Efficiency in Scotland", The Scottish Government, August 2012

to-treat", requiring the installation of higher-cost systems to improve their energy performance[6].

- In the EESSH consultation a significant number of the retrofit examples were of post-1982 construction. This reflects the changes to the minimum building standards and in particular U-values, occurring from 1990 onwards, which need to be captured. Examples, relating to later age bands were not provided, because higher specified U-values in building standards mean that it is unlikely that enhancement will be needed to achieve the EESSH.

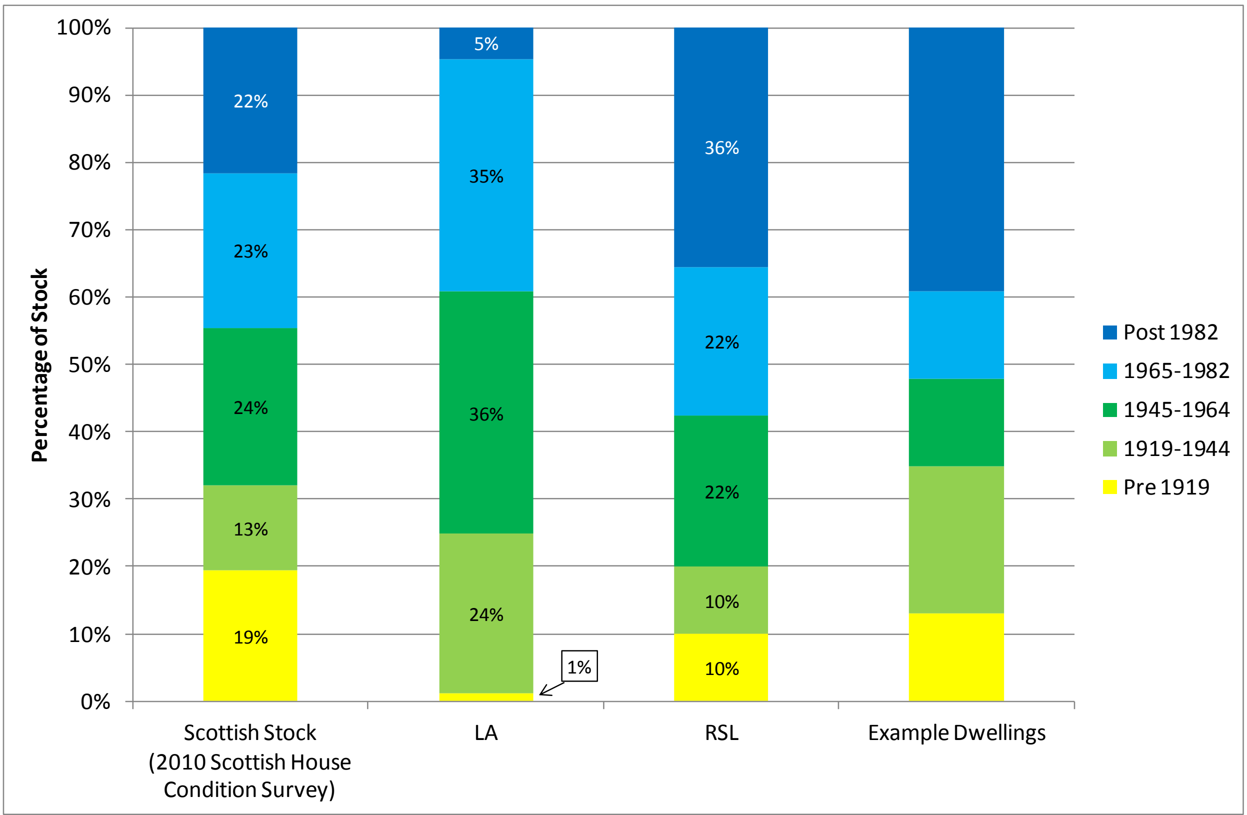

Figure 1 Distribution of the Scottish building stock by period of construction

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[6] „Guidance on meeting the energy efficiency requirements of the Scottish Housing Quality Standard", Energy Saving Trust, March 2008

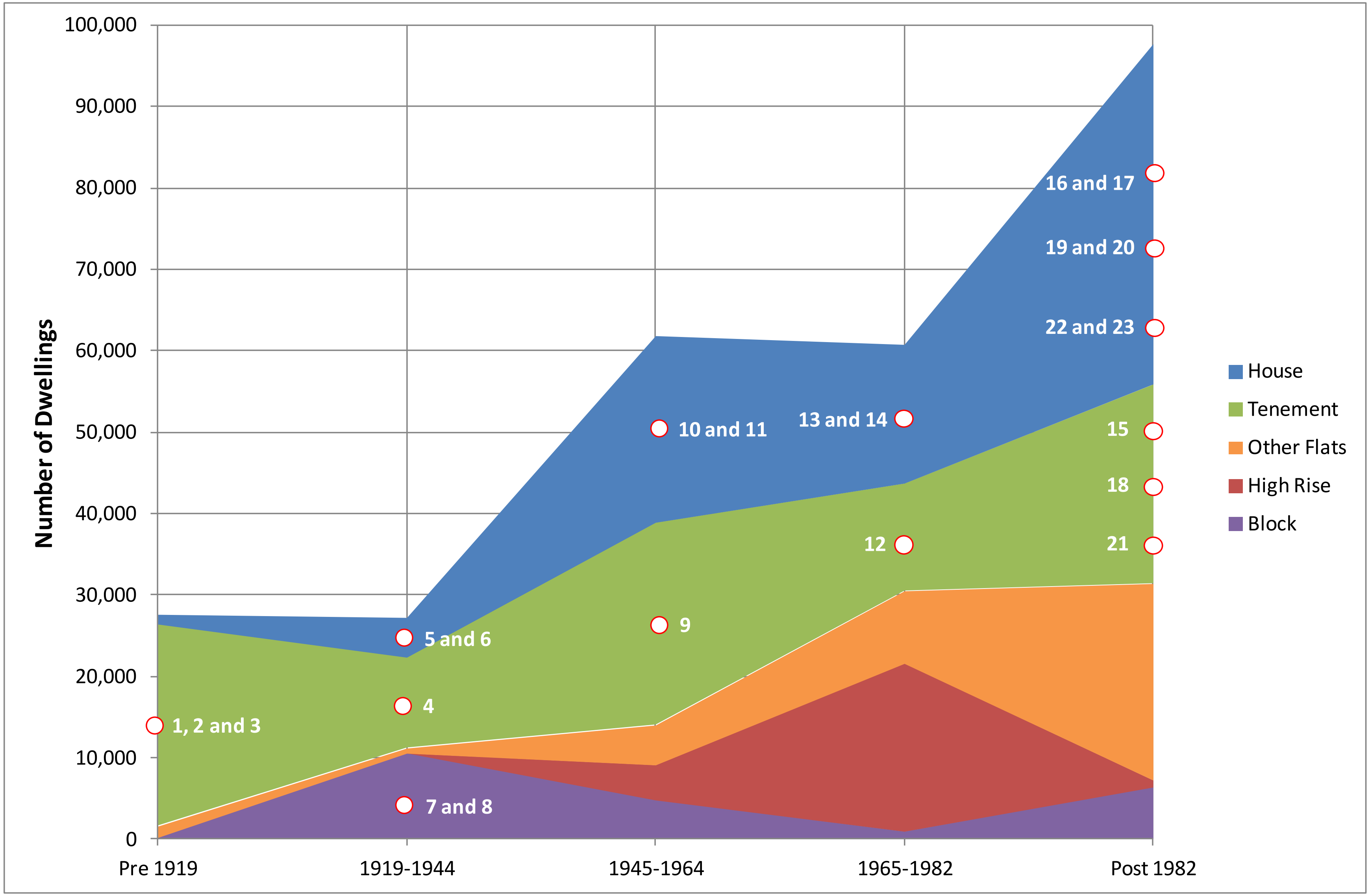

Figure 2 Distribution of the RSL Scottish building stock by building type and period of construction (numbers refer to example dwellings)

3.2 Commentary on retrofit examples

The assumptions for the first improvement stage, „SHQS 2015", were compared against the criteria outlined in Annex C of the SHQS. Annex C requires dwellings to meet sufficient insulation and heating system criteria (elements 31 to 34), and to attain a minimum NHER or energy efficiency (SAP) rating in relation to the fuel type (element 35 - see Appendix B). The „Further Measures 2020" stage is compared against the proposed Environmental Impact (EI) and Energy Efficiency (EE) ratings detailed by the EESSH consultation, relating to the calculated CO_2 emissions and operation costs respectively (see Appendix C). These are also referred to as „EPC ratings" within this report.

The following section summarises the key findings from the review of assumptions associated with each retrofit example, and highlights a number of factors which should be taken into consideration when using the data.

3.2.1 Building form

The example dwellings assume simple building forms. Therefore, it should be noted that any building feature which contributes to increased heat loss surface area, relative to the example dwellings, will result in higher space heating requirements. This will result in higher fuel bills and CO_2 emissions, and consequently lower (i.e. poorer) EE and EI ratings. This increase in heat loss area may be due to a number of factors, for example:

- An unusual floor layout resulting in a greater exposed façade area relative to the floor area (this will also prove detrimental to the ground floor U-value due to increased exposed perimeter length, contributing to further heat loss).
- A dwelling being adjacent to an unheated or partially heated building.
- A dwelling featuring an unusual building detail, such as a bay window or an overhang, contributing to an increase in the exposed construction area.

Section 5 of this report details a number of additional example dwellings which feature additional heat loss area (e.g. gable-end flats). The difficulty that some of these dwellings have in reaching the EESSH is discussed in sections 7 and 8. It should also be recognised that some specific features (such as bay windows, heated porches, large glazing ratios, etc.) make the suggested retrofit targets more challenging when modelled in RdSAP. Some of these dwellings will already fall into a conventional „harder-to-treat" category, where "harder-to-treat" is used to describe solid-wall construction or off-gas properties[7] but can also include homes with no loft or within high-rise developments[8]. It should however be noted that the EESSH consultation

[7] Centre for Sustainable Energy, Analysis of hard-to-treat housing in England, November 2011

[8] Defra/BRE/EST, A study of Hard to Treat Homes using the English House Condition Survey, 2008

takes account of off-gas housing by proposing a lower rating requirement for such properties. For those that do not meet existing harder-to-treat definitions (and it is suggested the number of such dwellings could be quantified), an additional "difficult-to-treat" definition might be required to recognise homes that, although not conventionally harder-to-treat, will have similar challenges in reaching, and funding retrofit measures for the EESSH.

3.2.2 Age band

Example groups C and H cover multiple RdSAP age bands (see table below). This has little impact for group C as the two age bands would be treated in similar ways. However the two RdSAP age bands covered by group H (1999 to 2007) assume different performance parameters, due to changes in the minimum Building Standards enforced from 2002.

The example dwellings in group H assume that systems are specified to the standards corresponding to the earlier RdSAP age band (1999-2002). The suggested improvement measures specified for example dwellings H21, H22 and H23 are relevant for both age bands within group H. However, the dwellings approved under more stringent building standards will demonstrate better energy performance characteristics. Reference could be made to Appendix D of this report to view a summary of the different performance specifications associated with the pre- and post-2002 building standards that will affect the RdSAP calculation.

<table>
<tr><th>Time Period</th><th colspan="2">EESSH Retrofit Examples</th><th>RdSAP 9.91
Table S1: Scotland</th></tr>
<tr><td>Pre 1919</td><td colspan="2">A. Pre 1919</td><td>Age band A: before 1919</td></tr>
<tr><td>1920-1924</td><td></td><td rowspan="6">C. Four in a block
1920 - 1949</td><td rowspan="2">Age band B: 1919-1929</td></tr>
<tr><td>1925-1929</td><td></td></tr>
<tr><td>1930-1934</td><td rowspan="4">B. Interwar
1930 - 1949</td><td rowspan="4">Age band C: 1930-1949</td></tr>
<tr><td>1935-1939</td></tr>
<tr><td>1940-1944</td></tr>
<tr><td>1945-1949</td></tr>
<tr><td>1950-1954</td><td colspan="2" rowspan="3">D. Post War
1950 - 1964</td><td rowspan="3">Age band D: 1950-1964</td></tr>
<tr><td>1955-1959</td></tr>
<tr><td>1960-1964</td></tr>
<tr><td>1965-1969</td><td colspan="2"></td><td rowspan="2">Age band E: 1965-1975</td></tr>
<tr><td>1970-1974</td><td colspan="2"></td></tr>
<tr><td>1975-1980</td><td colspan="2" rowspan="2">E. 1976 - 1983</td><td rowspan="2">Age band F: 1976-1983</td></tr>
<tr><td>1980-1984</td></tr>
<tr><td>1985-1989</td><td colspan="2">F. 1984 - 1991</td><td>Age band G: 1984-1991</td></tr>
<tr><td>1990-1994</td><td colspan="2" rowspan="2">G. 1992 - 1998</td><td rowspan="2">Age band H: 1992-1998</td></tr>
<tr><td>1995-1999</td></tr>
<tr><td>2000-2004</td><td colspan="2" rowspan="2">H. 1999 - 2007</td><td>Age band I: 1999-2002</td></tr>
<tr><td>2005-2007</td><td>Age band J: 2003-2007</td></tr>
<tr><td>Post 2007</td><td colspan="2"></td><td>Age band K: 2008 onwards</td></tr>
</table>

Table 1: Retrofit Example dwellings and RdSAP age bands

3.2.3 Walls

Cavity wall construction can lead to heat loss through party walls, subject to air movement between lower floors and the loft space. This is taken into account within the SAP methodology, but is yet to be recognised by RdSAP. It should be noted that in such instances, the total heat loss area may be greater than that represented by the RdSAP calculation.

Solid wall, system built and timber frame properties are recognised as harder-to-treat where they cannot accommodate cavity wall insulation. Internal or external wall insulation may be appropriate for some dwellings, but this technology can be limited in application due to a number of factors. For internal solutions the reduction in internal floor area, incompatibility with internal features and tenant disruption are limitations. External wall insulation is usually unsuitable for listed buildings and conservation areas and can be difficult to achieve where the dwelling forms part of a mixed tenure block.

Section 5 presents a number of additional example dwellings which can be considered harder or expensive to treat on account of wall type (including gable end solid wall dwellings, timber frame, „No fines" concrete and „BISF" steel frame construction).

3.2.4 Floors

For some properties with uninsulated timber and solid concrete floors, ground floor insulation can substantially improve energy efficiency but the installation process is often very invasive (particularly for solid floors), and may incur additional expense (e.g. decant of tenants and/or their belongings). Careful consideration needs to be given to the installation process to ensure minimal damage to lifted floorboards, and the provision of sufficient ventilation to mitigate the development of damp or rot. On this basis, the example dwellings note the installation of floor insulation as an „advanced measure".

The baseline U-value used by the RdSAP methodology for suspended timber floors (which are the default ground floor construction type for pre-1929 dwellings in Scotland) does not incorporate the benefits of insulation. In line with enhancements to the calculation methodology, documentary evidence applicable to the property being assessed (e.g. manufacturer specifications) must be retained for audit purposes if overwriting the default U-value associated with the floor, to account for the benefits and the thickness of insulation entered.

Research for Historic Scotland has provided an example of where the default U-values attributed to a solid concrete floor have been observed to differ significantly from those found by examples of *in situ* testing[9]. This means that, relative to the default U-values associated with the baseline performance, the dwelling would be subject to greater heat loss through the floor, and consequently greater energy and CO_2 emission savings would be expected post-application of the ground floor insulation.

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[9] *Energy Heritage – A guide to improving energy efficiency in traditional and historic homes* (Changeworks, 2008)

3.2.5 Lofts

There is limited data available to inform the 1990 baseline assumption for loft insulation. It has been observed that the age of the dwelling bears a strong correlation to whether the dwelling has any loft insulation (where there was no national requirement for new houses prior to the mid 1960‟s[10]). Appendix E summarises data from a number of sources, considering the level of loft insulation present relative to the age of the dwelling, and reporting the corresponding U-values. Based on this information, two changes to the 1990 baseline assumptions have been proposed, namely:

(i) Specification of 12mm loft insulation for 1965-1975 dwellings, as represented by example group D
(ii) Specification of increased loft insulation thickness from 100mm to 150mm for the baseline dwelling in example group G.

These changes will not affect the EPC ratings achieved by the improvement measures specified for dwellings in example groups D and G, and therefore will not compromise the ability of such dwellings to meet the SHQS or EESSH. They will however alter the energy performance of the 1990 baseline, and thus impact on the percentage improvement relative to this.

In relation to the period 2006 to 2015, installers and Government regulated insulation schemes specified insulation levels of 150, 200 and 250mm considerably exceeded the original SHQS standard. However, in the early 1990s some contractors and housing associations may have installed to the lower SHQS value. Meanwhile, more latterly it is more likely that the higher standard will have been specified. The current SHQS standard specifies 100mm for existing insulation and 270mm as desirable when „topped up‟.

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[10] „Implementing the Housing (Scotland) Act 2006, Parts 1 and 2: Advisory and Statutory Guidance for Local Authorities: Volume 4 Tolerable Standard‟, Scottish Government, March 2009

3.2.6 Open chimneys

Fireplaces are a common feature in older buildings. Therefore, some of the dwellings in groups A to D (up to 1964) could feature at least one fireplace for the 1990 baseline assumption. Examples without chimneys will have lower infiltration levels and space heating requirements for the 1990 baseline. As part of the validation exercise this was explored. One and two chimneys were modelled to provide social landlords with an understanding of how this would affect dwellings" energy efficiency and environmental ratings. This testing was separate from the re-modelling of the baseline. This is discussed further and the separate modelling results are detailed in the **Report Annex: Review and Validation of Consultation Case Studies (now Retrofit Examples).** The impact was not sufficient to change the overall banding of the property, or compliance with the standard.

3.2.7 Boiler efficiency

For pre-1998 boiler systems, the SAP methodology[11] states a winter efficiency of 66%, and a summer efficiency of 56-57% (with the exception of pre-1979 floor mounted boilers, and those that are not fan assisted). Such efficiencies are applied to the baseline dwellings in example groups A to G, and can be reduced by 5% where there are limited controls (e.g. no room thermostats or thermostatic radiator valves (TRVs)). The overall efficiency associated with the boiler will be dependent on the extent of the domestic hot water load, relative to the space heating load.

The building standards applicable at the start of the construction period represented by example group H (1999 to 2007) did not specify a minimum boiler efficiency. The target U-values, for exposed building elements, were determined using a seasonal boiler efficiency of 72% (this would be expected to correspond to a non-condensing system). As of 2002, amendments to building standards stipulated a minimum boiler efficiency of 78%, but this was also relative to improved U-value specifications, which have not been applied to the example dwellings. Based on the information detailed in the SAP methodology[12], winter and summer efficiencies of 74% and 64% respectively are considered appropriate for the group H baseline dwellings.

Standard 6.3 of the Domestic Technical Handbook[13] specifies a minimum seasonal efficiency of 88% (SEDBUK 2009) for gas boilers. It is proposed that the value used to describe the boiler efficiency for any future installations is no lower than 88% as it represents the minimum efficiency in current building standards.

For biomass boilers it should also be noted that while its EI rating is very good, RdSAP currently allocates a maximum 65% efficiency rating (and it should be noted that there are biomass boilers specified with far greater efficiencies), making it hard for biomass-fuelled properties to achieve a high EE rating.

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[11] Table 4b of the SAP methodology

[12] *Ibid*

[13] Scottish Domestic Technical Handbook, Section 6 – Energy (2011)

3.2.8 Lighting

Energy efficient lighting was not prevalent on the market around 1990, therefore 100% inefficient lighting as a baseline assumption is appropriate. As legislation pushes towards the phase out of GLS (tungsten filament) fittings, the assumption of 100% energy efficient lighting for the SHQS 2015 improvement measures seems reasonable.

3.2.9 Renewables

The effective installation of renewables such as photovoltaics (PV) or solar thermal is sensitive to a number of criteria, for example, orientation, roof space, roof angle, shading, storage space (for hot water) and ability of the existing hot water system to withstand a pressurised system. Should optimal conditions not be met for any of these criteria, additional costs may be incurred to improve the operational performance of the system (for example, investment in a supporting frame to improve the tilt angle or installation of multiple micro-inverters to overcome shading issues).

Given these considerations, renewable technologies should therefore be considered by the retrofit examples as „advanced measures", as opposed to being included in the „SHQS 2015" or „Further Measures 2020" improvement stages. These may, in some cases, be considered sooner by social landlords should they be appropriate for their housing stock. Renewables may, for example, be more widely applied in dwellings located off the gas grid. For these properties the displacement of the high costs and CO_2 emissions from oil, LPG fuel or electricity can yield significant financial and environmental benefits. In some cases this will be a cost-effective way of working towards compliance with the SHQS and improved EESSH. Payment levels from the RHI and Feed in Tariff (FIT) will be a major factor in these calculations.

3.2.10 Fuel source

Many of the dwellings surveyed for the 1991 SHCS were identified to have no central heating, particularly the older stock (almost half of pre-1919 social rented tenements). These homes featured systems different to those described by the electric- and gas-heated 1990 baseline example dwellings. It should therefore be remembered that the methodology outlines an approach to improve the current Scottish social rented stock, and does not represent actual CO_2 emissions reductions (relative to 1990 levels).

For pre 1919 flats electric heated example dwellings A-1(E) and A-2(E) and gas A-2 (G) are reliant on the application of „advanced measures" to meet the proposed target ratings for the EESSH, but this approach may not be suitable for all dwellings. Options are more limited for older mid-floor flats like A-2. For those located on or near the gas-grid, fuel switching to gas heating may offer a cost-effective way of attaining the highest possible EPC rating band.

Fuel source needs to be considered early on in an overall plan to reduce the buildings CO_2 emissions, where it will alter the target compliance ratings and influence subsequent technologies installed. Particularly in relation to electric heating, it should be recognised that certain areas of Scotland actually promote electric heating as an affordable and environmentally sustainable heating source. In Orkney[14], for example,

[14] http://www.oref.co.uk/ provides more information.

the high volume of renewably-sourced electricity means that electric storage heating systems provide valuable support to the distribution network. Electric storage allows generation peaks from intermittent renewables to be stored and matched with demand peaks. Against this context, households in this area are currently being encouraged to move from high-emissions fuels such as oil and solid fuel to storage electricity and heat pumps. However, because electric-heated properties achieve low EI ratings, they could face additional challenges in meeting the EESSH, depending on what fabric improvements are possible.

Over time the EI of electric heating is likely to improve as the grid is decarbonised. This should be considered in relation to how technologies such as electric storage heaters and heat pumps will relate to the standard in future. For example, a system installed and modelled today will have a significantly better EI if still in operation in 2020. This assumes the Scottish Governments targets for renewable energy productions are achieved.

3.3 Assessment and modelling

3.3.1 Skill of the assessor

The RdSAP calculation plays a significant role in terms of demonstrating compliance for both the SHQS and EESSH. This places a high importance on the skill of the assessor. In addition, a number of the inputs to the RdSAP calculation are subject to the judgment of the assessor, and can have a significant impact on the results. For example, the ability to identify a typical glazing area relative to the age and form of the building will impact on the dwelling‟s average U-value, and consequently space heating requirements, fuel costs, and CO_2 emissions. A significant issue in RdSAP 2009 9.91 is the ability to input actual U-values, whereas previous versions relied solely on default values. Based on plans, a skilled assessor will be able to identify variations from default U-values for some buildings of non-traditional construction. In other cases research evidence is needed from in-situ testing. For example, solid walls in pre-1919 buildings can have much better U-values than the SAP defaults, as can more modern concrete floors; while single glazing can have significantly worse U-values than the default assumptions[15]. Documentary evidence of in-situ testing must be retained by the assessor for audit purposes if they overwrite any default U-value in RdSAP (more details on this are provided in Section 5.2).

3.3.2 Modelling packages of measures

The example dwellings outline a set of cumulative improvement measures across three stages; „SHQS 2015‟, „further measures 2020‟ and „Advanced Measures 2050‟. It is important to emphasise that the effect of measures applied across different improvement stages cannot simply be added together: the extent of the savings realised by any individual measure will be dependent on other efficiency measures in place. For example, installing improved glazing in a dwelling with an inefficient boiler will demonstrate greater savings compared to the same installation in a dwelling with an efficient boiler.

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[15] See research by Historic Scotland, SPAB and Changeworks among others

The example dwellings do not prescribe a route to compliance but can be used by social landlords to inform the development of an energy efficiency plan, or appreciate the extent of measures necessary to meet the target ratings. Some of the proposed technologies may not be universally suitable. For example, budgets and replacement cycles may restrict the potential to upgrade glazing in the short to medium term, especially where older double glazing has been installed in the late 1990s or early 2000s. In such cases, the measures can be factored into longer-term plans for compliance. A range of measures should therefore be used to identify improvements of sufficient scale to comply with the standard. Any measures that may not be immediately cost-effective (e.g. triple glazing) may prove relevant to meeting future requirements.

3.4 Options for listed buildings

Older building stock can often be listed buildings or have other conservation status, which will restrict the application of measures, deemed to significantly change the appearance or character of the building.

Social landlords will need to correspond with their local planning authority to determine the likely impact and consequences of any limitations, and identify measures which are deemed acceptable. The Scottish Government may wish to accept documentary evidence from landlords in cases where properties are prevented from meeting the standard due to such planning regulations.

3.4.1 Glazing

Almost all the example dwellings in groups A to C consider the replacement of single glazing with double glazing, but this cannot always be accommodated where the building is listed or otherwise protected.

3.4.2 Wall insulation

The application of this measure may also be restricted in some older and/or listed buildings due to internal features or an excessive reduction in the internal floor area. Internal wall insulation products that are recommended by Historic Scotland for breathability (important to the health of solid masonry walls) do not attain a sufficient U-value to attract ECO support.

Costs for the „specialist‟ improvement systems that are often needed in older listed buildings are generally considerably higher than for more standard systems; not only is this not accounted for in the examples‟ cost assumptions, but this is also likely to be a considerable barrier to uptake for some social landlords.

4 Validation of Existing Retrofit Examples

4.1 Modelling Overview

The consultation document was accompanied by a set of draft retrofit examples, demonstrating how the standard might be met in different property types. Changeworks re-modelled these retrofit examples and validated the inputted energy modelling data presented. Each retrofit example was re-modelled (using both gas and electric heating), and changes noted. The outcomes for re-modelled retrofit examples are provided at Appendix F. Detailed commentary and validation is provided for each example in the **Report Annex: Review and validation of Consultation Case Studies (now Retrofit Examples).**

At the time of re-modelling these examples, the new version of RdSAP 2009 (v9.91) was not available (this has subsequently been launched); therefore, RdSAP 2009 (v9.90) was used to validate the examples. This was a much newer version of the software than was used by the Scottish Government (SAP 2005 (v9.83). Aside from the minor issues set out in table 2 below the baseline assumptions were deemed to be valid by Changeworks‟ modeller and were therefore not altered[16]. However, despite the consistency in inputs it became apparent that that the outputs were sensitive to software changes. It is anticipated that the difference between version RdSAP 2009 9.91 and 9.90 will be less significant than versions RdSAP 2005 v9.83 and RdSAP 2009 v9.90.

4.2 Changes to Modelling

Only minor changes were made to the input assumptions. These related to example 11E where the roof area utilised for PV was boosted from 10% to 20% to accommodate an adequate system output. This was consistent with the other retrofit examples utilising this technology. Some rogue values were in the text for retrofit example, 12G in relation to the 2050 advanced measures. No advanced measures could be identified so values in this column were deleted. Meanwhile, examples 16E, 16G, 17E and 17G saw changes to the baseline assumption on floor insulation, because this would not have been specified by building regulations or likely to have been installed prior to 1990. Table 2 (below) summarises changes identified as part of the validation exercise.

[16] The Technical Annex describes some alternate assumptions and their impact on baseline performance

Changes to Case Studies (now Retrofit Examples) in the Consultation Document

Retrofit examples	Changes made
D-11E	This retrofit example in the consultation document states the PV modelled was 10% of roof space. However, this was estimated to cover 5.15m^2 of roof space. Instead, 20% of roof space was selected. This would be estimated to cover 10.3m^2 and also be of a proportion consistent with the other retrofit examples which have been modelled at 20%.
E-12G	There were SAP and EI ratings for advanced measures 2050 shown in the consultation document but there were no measures listed as being carried out between 2020 and 2050 in the document. There was a jump of the SAP rating from B (84) to B (87) between 2020 and 2050 in the consultation document. All energy efficiency measures had been carried out up until 2020, so there were no measures that could be accounted for to improve the SAP by 3 points. Therefore no improvements were made for the 2050 standard in the re-modelling.
F-16E	This retrofit example in the consultation document stated that for the baseline the floors had been insulated. However, using the "as built" floor construction for this period (1984-1991), on the RdSAP software, the software assumes that the floor is un-insulated. Therefore "no insulation" was used as opposed to "insulation" for this baseline. The rest of the re-modelling for this retrofit example was consistent with that carried out in the consultation document.
F-17E	See F-16E comment
F-16G	See F-16E comment
F-17G	See F-16E comment

Table 2: Changes to Case Studies (now Retrofit Examples) in the Consultation Document

4.3 Alternative approaches and assumptions

Apart from the above changes, the validation exercise identified alternate approaches and assumptions which are discussed in the **Report Annex: Review and validation of Consultation Case Studies (now Retrofit Examples)** for each example. For example, alternate baseline values could be specified for chimneys and hot water tank insulation but it was found that overall impact wouldn‟t change the EI or EE rating band of the properties. Alternatives to the retrofit examples were modelled to explore and illustrate sensitivity; these are discussed in more depth in Annex A. Whilst there was some movement in the EI and EE rating it wasn‟t felt sufficient to warrant remodelling all the examples. Instead social landlords should be aware of this factor, when considering the baseline of their stock.

The depth value specified for loft insulation installed in the period between the baseline and compliance between 1990 and 2015 didn‟t correspond with building standards in the later part of this period. Instead it matched the SHQS minimum standard of 100mm. Given the lack of data on loft insulation levels and variations due to install date it was felt to be safer to retain this as a worst case scenario. In practice many social landlords and installers will have installed up to 250mm. For these landlords the top-ups specified in the retrofit examples wouldn‟t be required.

4.4 Overview of impacts of the new version of RdSAP

The following summary table shows where the EE or EI band has changed when re-modelled using a more up-to-date version of RdSAP. Areas in grey indicate no change, values in white show original values which have been altered. For the corresponding changes red values indicate lower bands and green indicates a higher band.

Retrofit examples	Consultation draft								Remodelled							
	Baseline		SHQS		2020		2050		Baseline		SHQS		2020		2050	
	SAP	EI	SAP	EI	SAP	EI	SAP	EI	SAP	EI	SAP	EI	SAP	EI	SAP	EI
1E			E								D					
2E			D								C					
3E		F						C		G						D
1G	D			D			B		E			E			C	
2G			C		B		B				D		C		C	
3G					B		B						C		C	
4E		D		C	C		C			E		D	B		B	
5E		F	D							G	C					
6E	G		D						F		C					
4G																
5G		F								E						
6G								C								B
7E	F		D				D		E		C				C	
8E	G		D	D				C	F		C	E				D
7G				E								D				
8G							A								B	
9E	D	D			C				C	E			B			
10E	F		D	D					E		C	E				
11E	G		D				D		F		C				C	
9G																
10G		F		E						E		D				
11G						D	B							C	C	
12E	D								C							
13E	F								E							
14E	F		D						E		C					
12G	C								D							
13G		F								E						
14G				E								D				
15E					C								B			
16E	E		D	D					D		C	E				
17E		E			D		D			F			C		C	
15G																
16G							B								C	
17G							B								C	
18E		C								D						
19E			D	D							C	E				
20E	E				D	D			D				C	E		
18G					B								C			
19G																
20G							B								C	
21E	C								B							
22E	D						C	C	C						B	D
23E	D	D							C	E						
21G	D	C							C	B						
22G	D					C	C		C					B	B	
23G	D	D			D		C	C	C	C			B		B	B

** For the re-modelled figures, red denotes where the rating becomes worse as a result of the re-modelling and green denotes where it has improved.*

Table 3 Summary of re-modelling changes to SAP and EI bands

A full breakdown and comparison of the changes in EI and EE is provided in appendix F. This includes a full summary of the remodelled EE & EI for the baseline, SHQS period, 2020 and 2050. A summary of each remodelled retrofit example and the applied measures are provided in Appendix G.

4.4.1 Significant software related variations

The re-modelled version of retrofit example study 21G (1999-2007 mid-floor flat) showed a noticeable variation from the result in the consultation document modelled using RdSAP 2005. The post-improvement results presented in the consultation document are considerably greater than were achieved when remodelled; the reasons for this are not clear. Based on Changeworks" knowledge and use of the previous and new versions of RdSAP 2009 (v9.90 and 9.91 respectively), we would not anticipate that using version 9.91 would throw up such major differences unless user defined values were substituted for defaults.

Some changes in the newest version of RdSAP 2009 (v9.91) are straightforward, e.g. the need to enter the thickness of solid walls, check for the presence of dry-lining, the ability to model draughtproofing and the ability to account for location. However, any significant changes in the modelling are most likely to arise from entering the optional additional data that version 9.91 allows (e.g. actual U-values, insulation specifications, window orientation, etc.), as in some cases these could vary significantly from the default values. As discussed previously, these additional data are optional, and in many cases it is unlikely that these would be collected by the property assessor.

To aid understanding of these issues, a small sample of the examples was re-modelled using the new version of RdSAP, both with and without the optional additional data entered. The findings are outlined in Section 5.2.

4.5 Other findings

Throughout the re-modelling, percentage improvements in CO_2 emissions and energy usage are similar to those presented in the consultation document. There are however some major differences in the EE and EI results, but mainly for electrically-heated properties. As previously stated this can only be the result of using an older version of RdSAP 2005.

4.5.1 Electrically-heated retrofit examples

For the electrically-heated retrofit examples, the EE ratings are **higher** and EI ratings **lower** than those presented in the consultation document. Changeworks compared an alternate model of these retrofit examples generated using a different software programme[17], which resulted in EE ratings that were very close to those presented in the consultation document. There are likely to be numerous reasons for these variations (e.g. different CO_2 factors), however most are likely to be the result of using different versions of RdSAP.

[17] NHER Stock Assessor – this uses an older version of RdSAP, v9.83 (which uses SAP 2005).

4.5.2 Gas-heated retrofit examples

For the gas-heated retrofit examples, the SAP ratings are in most cases **lower** and EI ratings **similar** to those presented in the consultation document. As with the electrically-heated retrofit examples, some of these differences may be accounted for by the different versions of RdSAP being used.

The following should also be noted when comparing the gas-heated retrofit examples with the re-modelled versions:

- The consultation document uses a 60% efficient boiler for the baseline. More recent versions of RdSAP are unable to model this, as the assumed efficiency of a wall-mounted boiler is 66%[18]. This 66% figure was therefore used for the re-modelling.

- The consultation document uses a 90.9% efficient boiler for the improved heating system. However, there are no such mains gas combi condensing boilers[19] on the SEDBUK database so a 90% efficient boiler[20] was used for validation.

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[18] The only sub-66% efficient boiler that could be modelled using RdSAP is a pre-1979 floor-mounted boiler, which has an assumed efficiency of 56%.

[19] There are however other types of boilers and fuels that show greater efficiencies.

[20] Ravenheat HE 85 A.

5 Additional Retrofit Examples

As noted in section 3 of this report and in the Peer Review brief, additional retrofit examples were required in order to provide a more thorough cross-section of social housing property types. Twelve additional retrofit examples were prepared; these are summarised in Appendix H. The selection process took account both of property types not included in the EESSH consultation document, and of the need to represent hard-to-treat (or expensive-to-treat) properties. The final list of property types was agreed after negotiation with the Scottish Government.

5.1 Additional retrofit examples

The table below details the twelve additional retrofit examples, specifying properties that have been double-tested using both default and calculated specifications.

	Hard-to-Treat (HTT) Property type	Sub-archetype	Default or calculated U-values applied
HTT1	Pre-1919 tenement flat	Ground floor, gable end	**Both**
HTT 2	Pre-1919 tenement flat	Top floor, gable end, partial flat roof	Default
HTT 3	Multi-storey flat	Ground floor, gable end	Default
HTT 4	Multi-storey flat	Mid-floor, gable end	Default
HTT 5	External deck access flat	Ground floor, gable end	Default
HTT 6	External deck access flat	Mid-floor, gable end	Default
HTT 7	No Fines concrete flat	Ground floor, gable end	**Both**
HTT 8	No Fines concrete flat	Top floor, gable end	**Both**
HTT 9	Swedish timber house	Semi-detached	**Both**
HTT 10	1950-1982 timber house	Semi-detached	Default
HTT 11	System-built concrete house	Semi-detached	Default
HTT 12	BISF steel frame house	Semi-detached	Default

Table 4: Additional Retrofit Examples

For the flats, two sub-archetypes were selected, in order to provide a level of comparison without the excessive detail of modelling all possible sub-archetypes. In most cases, flat sub-archetypes (e.g. floor level, gable end) were chosen to illustrate the worst-performing sub-archetypes. However, this is not the case for mid-floor flats: while top-floor flats would achieve a worse baseline, mid-floor flats were generally selected in order to be consistent with the existing retrofit examples. Mid-floor flats are also more prevalent.

Two timber house archetypes were chosen, as the Swedish timber house type generally achieves a higher baseline energy efficiency rating than standard older timber frame houses.

As with the original retrofit examples, each of the above property types was modelled with both gas and electric heating.

All twelve new retrofit examples were modelled using the new version of RdSAP (9.91). Due to the constraints of the software, many of the different non-traditional house types are likely to be treated similarly by RdSAP. In order to provide further analysis and validation in this respect, a third of the examples were modelled twice, once using the „basic" version of RdSAP and once inputting the optional additional data elements (e.g. actual U-values, insulation specification, etc.), in order to identify any key discrepancies.

5.1.1 Commentary on additional retrofit examples

A full list of retrofit measures, applied across different standard periods is provided in Appendix H. An overview of measures and outcomes for the full suite of the original 23 retrofit examples as remodelled and the additional example dwellings from this chapter is provided in Appendix H. Further commentary is provided below.

5.1.2 Non-traditional construction

Non-traditional construction accounts for a large proportion of the additional retrofit examples. While it was felt important to cover these property types, it should be noted that the examples are by necessity generic and in most cases were modelled on a worst-case scenario basis. In reality, many landlords may find some or all of their non-traditional stock has been improved since it was built, so their starting baseline may differ from that shown in the examples. (However, it should also be noted that many such improvements may have been more for aesthetic than energy efficiency reasons, e.g. brick overcladding to improve the appearance of the façades.)

Also with regard to non-traditional stock, the limitations of RdSAP must be recognised. As mentioned above, some of the different non-traditional construction types may be treated similarly by the software and so the variations could be limited. Different concrete construction types in particular may suffer from this; for example, system-built properties which could encompass a wide range of stock types would effectively be treated the same by RdSAP.

5.1.3 Flats

With regard to the flats covered by the additional retrofit examples, two sub-archetypes were selected in each case for reasons outlined above. Clearly, archetypes not included will perform differently and realise different savings from refurbishment. The inclusion of partial flat roofs on the pre-1919 flats was felt to be important, as this is particularly common in the later (e.g. Victorian) traditional tenements. In these properties the roofs are commonly either mansard or a mix of pitched and flat, in many cases the flat-roof area accounting for around two thirds of the total roof area. This is often overlooked when considering traditional tenement improvements, but it is important to bear in mind as flat-roof insulation is notoriously complex and rarely undertaken unless the roofs are being renewed.

5.2 RdSAP Remodelling with non-default values

As noted above, some of the retrofit examples were modelled twice, both excluding and including the additional data elements offered by RdSAP. It is important to reiterate that these additional elements are optional only, and as their inclusion will require additional time by the assessor and possibly additional costs, it seems likely that in most cases they will not be included in the survey.

As detailed in the table 4 in (Section 5.1 above), the following retrofit examples were modelled twice, using both default and calculated U-values and insulation specifications:

- Pre-1919 tenement flat (HTT1)– ground floor, gable end
- No Fines concrete flat (HTT7)– ground floor, gable end
- No Fines concrete flat (HTT8)– top floor, gable end
- Swedish timber frame house (HTT9)– semi-detached

For each of these comparisons, using specified rather than default values changes the performance ratings and predicted impacts of improvement measures.

5.2.1 Enhance Baseline Example

This can work both ways: for example, the **ground-floor No Fines flat** achieves a better baseline (1990) performance when using actual specified values, however this improved starting point then lessens the impact of the improvement measures, so the benefits of the improvement measures are proportionally greater when using the default values (even though these predicted benefits are unlikely to be achieved in reality.)

Again, the **pre-1919 tenement flat** shows noteworthy discrepancies when using default or actual specifications and capital costs. Examples include the following:

- Concrete floor – RdSAP"s default U-value for an uninsulated concrete floor is 0.5, however *in situ* measurements have recorded U-value as poor as 3.5 – a considerable variation. Indeed, this variation is so large that RdSAP is unable to input the actual U-value: its range is from 0.1 - 2.3, so 2.3 was used as the calculated U-value. Post-improvement, the default U-value is 0.28 (for an unspecified insulation material or depth), in comparison some *in situ* measurements have shown a U-value of 0.6 – again, a particularly significant difference given that this measured improved U-value is shown to be worse than the default unimproved U-value.

- Windows – For single glazing, the *in situ* measured U-value is 5.5, compared with RdSAP"s default U-value of 4.8. However, the poorest U-value permitted by RdSAP is 5.1 so this was used as the calculated U-value. *In situ* measurements showed secondary glazing to give a U-value of 2.3; again this differs from the defaults available within RdSAP.

- Walls – RdSAP"s default U-value is 2.0, compared with the *in situ* measured U-value of 1.4.

The tables below illustrate the differences in predicted impacts for an electric-heated pre-1919 tenement flat when using default or calculated U-values. Band changes are highlighted in bold:

1. DEFAULT	Baseline (1990)	SHQS	2050
SAP rating	44	58	72
SAP band	E	D	C
EI rating	25	34	52
EI band	F	F	E

Table 5: SAP 9.91 default calculation for pre 1919 tenement

2. CALCULATED	Baseline (1990)	SHQS	2050
SAP rating	23	39	67
SAP band	**F**	**E**	**D**
EI rating	8	18	45
EI band	**G**	**G**	E

Table 6: SAP 9.91 user defined calculation for pre 1919 tenement

For this property, using actual specifications shows the property to be less efficient than would be assumed by RdSAP if default U-values were used, both pre- and post-improvement. Similarly, using actual costs for the secondary glazing and floor insulation (both high-specification products with high associated costs, selected to cater to conservation-grade properties) significantly affects the payback periods. Irrespective of these costs, the choice of whether to use default or calculate specifications is shown to change both the EE and EI bands for this property type – with fundamental implications for whether they meet the EESSH.

5.2.2 Reduced Baseline Example

However, the situation changes in other cases. For the **Swedish timber frame house**, using the calculated U-values and insulation specifications shows the property to have a better performance both at baseline and post-improvement than would be predicted by relying on the default figures. Some key points in relation to this property:

- The default wall U-values (baseline 2.0, improved 0.6) were based on an assumed baseline performance and application of either an unknown internal or external wall insulation system. This is in comparison with the calculated U-values (baseline 1.24, improved 0.25) which were based on record drawings of the wall construction and specification of insulation materials.

- Similarly, the default improved floor U-value (0.35) was based on application of an unknown floor insulation retrofit, while the calculated improved U-value (0.17) was based on specified 170mm insulation.

The inclusion of specified values is therefore significant. In some cases the differential between the default and specified values actually pushes the property into a different SAP or EI band. For example, the following tables show predicted performance for the (electric-heated) Swedish timber frame house property using 1) default values and 2) specified values. Band changes are highlighted in bold:

1. DEFAULT	Baseline (1990)	SHQS	2020	2050
SAP rating	22	52	66	73
SAP band	F	E	D	C
EI rating	7	28	44	51
EI band	G	F	E	E

Table 7: SAP 9.91 Default calculation for Swedish timber frame house

2. CALCULATED	Baseline (1990)	SHQS	2020	2050
SAP rating	29	59	70	79
SAP band	F	**D**	**C**	C
EI rating	13	36	50	60
EI band	G	F	E	**D**

Table 8: SAP 9.91 User defined calculation for Swedish timber frame house

Tables 7 and 8 show that using the calculated values improves the SAP rating in three cases (SHQS, 2020 and 2050). This is particularly important when the property‟s rating is close to achieving the next SAP band and could be the difference between reaching or missing the standard. Where there is documentary evidence, the landlord‟s assessor will have the option to specify values that vary from the RdSAP defaults which could mean less effort is required to achieve the standard.

5.2.3 The implications of using non-default U-values

Overall, the consequences of using default U-values are not always clear in terms of meeting the EESSH. In some cases, inputting the optional additional data will show improved performance over the default predictions – and therefore be beneficial to the landlords – but in other cases it could shift the baseline and thereby reduce the impact of the improvement measures –making it harder to meet the standard. It seems likely that in many cases default values will be used for the baseline performance, with calculated values being entered for the improvement elements.

To help make predicted impacts more accurate in the future, the Scottish Government may wish to investigate the possibility of promoting or requiring the use of calculated rather than default U-values for certain building elements of improvement measures, where there is documentary evidence that they are materially different. Such an approach could draw upon the Department of Energy and Climate Change‟s (DECC) methodology for Green Deal and ECO of in-use factors (although this applies to all measures rather than just some). For a Green Deal Assessment, „in-use factors‟ will have to be applied to savings predicted by RdSAP to make the predictions more realistic. These factors will be reviewed and updated over time as new research and monitoring results become available[21]. Subject to certain changes (see next paragraph) it may be possible for the Scottish Government to adopt a similar approach for measuring performance of social housing stock using RdSAP: a set of calculated baseline and post-improvement U-values could be drawn up for different building and improvement elements. Social landlords could use these wherever appropriate in place of the RdSAP default figures. These calculated U-values would be obtained from current research[22], and if necessary additional *in situ* testing, allowing them to be updated periodically as new research and monitoring results become available. This mechanism would limit the gap between predicted and achieved performance, reinforcing social housing‟s contribution to Scottish Government targets.

5.2.4 Evidence supporting the use of non-default U-Values

The feasibility of this is largely dependent upon what constitutes „documentary evidence‟ of revised U-values. At present such „documentary evidence‟ must be either „relevant building control approval‟ or a calculation „produced or verified by a suitably qualified person‟[23]. This presents a potential barrier. Firstly, it requires documentary

[21] *How the Green Deal will reflect the in-situ performance of energy efficiency measures* (DECC, 2012)

[22] Currently this research is predominantly focused on older, traditional housing; robust results are however available from established sources such as Historic Scotland and SPAB.

[23] http://www.bre.co.uk/sap2009/page.jsp?id=2792

evidence for each specific building. Secondly, it is likely to require a „suitably qualified person": this means being a member of a scheme recognised by an approved domestic assessor protocol organisation or other professional body. At the time of writing it is not clear which assessors trained in Scotland are approved to do this under their scheme protocol. If the requirement for building-specific evidence was modified and robust research reports were to qualify this evidence this would aid assessors and other professionals (e.g. architects). In the longer term the calculations behind the default U-values within RdSAP are likely to be updated [24], however it is uncertain when these updates will take account of the above U-value research and it may prove beneficial for the Scottish Government to consider work focused on common social housing archetypes.

Subsequent to this modelling, DECC published finalised guidance on the operation of the ECO. This states that only types of solid wall insulation achieving a U-value of 0.3 to be eligible for support under CERO (which focuses on SWI). This is significant as the default 50mm insulation in RdSAP only achieves a U-value of 0.6. When designing and modelling a project, social landlords will have to specify a default of 150 mm of insulation to achieve a U-value of 0.25. This option is available in the new version of RdSAP 2009 v9.91. The Scottish Government and housing associations should be aware of these issues and monitor whether any complications arise when modelling specific products for the purpose of seeking ECO.

5.3 Other observations

The additional retrofit examples do not cover housing stock that is protected by planning regulations, e.g. listed buildings or those in conservation areas (as referenced in section 3.2.13). In such cases, the retrofit examples will be of more limited applicability as several of the potential improvement measures may either not be permitted or may require use of specialist systems incurring significantly greater costs. Examples include the following:

- Double glazing – may not be permitted, or may require specialist systems
- External wall insulation – unlikely to be permitted
- Internal wall insulation – may require a specialist system
- Gas boilers – may not be permitted in situations where flue would be sited on principal elevation

Guidance on costs and application of more specialist measures for such properties are available from other sources[25].

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[24] For example, at the time of writing this Peer Review DECC issued a tender invitation for *'Research to provide better estimates of solid wall insulation savings through improved understanding of heat losses'* (December 2012), which it anticipates will inform updates to RdSAP, SAP and the Green Deal.

[25] Changeworks, the Energy Saving Trust, Historic Scotland, Sustainable Uist among others.

6 Communal Improvements

This section provides commentary on how communal improvements can be adequately accounted for in the EESSH. It is important to recognise that many of the measures discussed can yield benefits in the form of reduced energy consumption, CO_2 emissions and fuel bills, however the RdSAP methodology does not take account of them, which means the effect of these will not be captured by the EPC ratings.

Some technology-specific issues are as follows:

6.1 Draught-proofing

The RdSAP methodology assumes all flats and maisonettes benefit from a draught lobby, and all houses and bungalows do not, without any consideration of the actual draught-proofing specification. This will impact on the infiltration calculated for the dwelling, consequently affecting the space heating requirements.

Any efforts to reduce heat loss from an unheated common area, such as draught-proofing, will yield benefits for the connected dwellings by reducing heat loss. However, the RdSAP methodology will not include these improvements in the calculated EPC ratings.

Aside from developing and researching a tool additional to RdSAP, it is difficult to see how this issue can be addressed. In this respect this review found very few and limited examples of projects where actual CO_2 savings were monitored and recorded. It is suggested that where some dwellings within multiple units marginally miss or are close to reaching the proposed ratings, landlords could be given credit for measures such as draught lobbies and draught proofing of communal areas. This would require assessment on an individual basis.

6.2 Communal corridors

The new version of RdSAP 2009 (v9.91) enables more detail treatment of internal corridor wall of properties (i.e. 'sheltered corridor' wall), in comparison to the previous version (v9.90). This enables an assessor to specify alternative walls types for the sheltered wall which can be insulated thereby increasing the EE rating of the adjoining properties. Previous versions of RdSAP assumed that both the sheltered and outer wall would have similar characteristics.

6.3 Efficient Lighting

Replacement of communal lighting with energy efficient fittings can achieve significant savings in energy, CO_2 emissions and fuel bills, particularly for lights which are subject to extended periods of use (e.g. stairwell lights which remain on all night). As with the draught-proofing of communal areas, this will not be taken into account by the RdSAP calculation for individual dwellings, and thus will not improve the EPC rating.

This issue is further complicated in terms of how these costs are accounted for and passed onto tenants, e.g. as part of rent or service charges. Costs may be spread between dwellings as part of a central contract, for example. In some cases (e.g. older tenements), lighting costs might be borne by the local authority as part of the street lighting budget. It would therefore be difficult to account for these improvements in the standard, although it could reference and promote them.

6.4 Community heating

The introduction of a community space and water heating system can help achieve CO_2 emission reductions, but will require careful design and specification to ensure this aim is realised.

This approach is particularly relevant for harder-to-treat dwellings, where previous reports have shown community heating or CHP systems to assist tower block flats in meeting the SHQS criteria, without any additional insulation measures, however such insulation will of course increase energy efficiency. Retrofit examples also highlight the benefits with regards to lifting occupants out of fuel poverty[26].

It is important that social landlords fully appreciate the differences between the calculated energy requirements (determined by RdSAP), and the actual operation of a community heating system. As an example, the following section considers a gas communal heating system and discusses a number of factors to be taken into consideration when assessing the operational performance.

6.4.1 Boiler efficiency of communal boilers

Reports have highlighted the importance of a high-efficiency boiler for communal systems[27], however table 4a of the SAP methodology specifies an efficiency of 80% for all gas communal boilers serving existing dwellings (the figure is slightly lower for communal CHP systems). Whilst the benefits of a more efficient system may not be represented by the EPC ratings; in practice, greater energy, CO_2 and fuel bill savings will be realised for the occupants.

Communal boilers, addressing both space and water heating, provide more benefit over individual systems where the „winter" boiler efficiency is applied all year round; normally a lower „summer" efficiency is used for the domestic hot water (DHW) calculation[28]. This will contribute to a better overall efficiency, lower energy requirements and consequently lower fuel bills and CO_2 emissions.

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[26] „Guidance on meeting the energy efficiency requirements of the Scottish Housing Quality Standard", Energy Saving Trust, March 2008

[27] „Greendykes House and Wauchope House energy assessment validation, Changeworks Consultancy, August 2012

[28] Section C2 Boiler efficiency, Appendix C, SAP 2009 version 9.90

6.4.2 Additional Energy Requirements

An advantage of installing a new communal heating system is that optimal controls and specifications can be detailed, in an effort to mitigate any further increase in energy requirements. Factors to consider include:

- Distribution losses associated with the network connecting the heat source to each dwelling. (Table 12c of the SAP methodology details the distribution loss factors which need to be applied, should the community system meet a number of criteria[29]. The factors range from 1.20 to 1.05, with the lower values describing modern systems.)
- Electrical energy is needed to pump water through the distribution system. (This is accounted for by adding electrical energy equal to 1% of the energy required for space and water heating[30], and will contribute to an increase in fuel costs and CO_2 emissions, affecting both the SAP and EI rating.)
- Efficiency adjustments as specified in table 4c of the SAP methodology (these are applied by multiplying the energy use by a factor ranging from 1.0 to 1.1 in relation to the control strategy.)

6.4.3 Fuel Costs

The SAP methodology allocates a unit cost for gas supplying a communal gas heating system of 3.78 p/kWh, which is greater than the unit cost for an individual gas boiler of 3.10 p/kWh[31]. These higher costs for community heating take into account bulk rates for buying the fuel used in the plant, operating costs, and energy used in pumping the hot water[32]. The effect of this is an increase in fuel costs, which will contribute to a lower SAP rating. The CO_2 emission rate per kWh remains unchanged.

The costs to landlords of gas safety checks and maintenance of individual boilers are not included for standard gas systems but they will be indirectly passed onto tenants. Hence, RdSAP may not reflect the full costs to tenants of communal systems. However, this is a moot point if electric heating is being replaced and individual gas systems are not technically feasible.

Again, when enforcing the standard, the Scottish Government may want to look favourably on landlords installing district heating systems where some properties are close to reaching the proposed ratings. Limited research may also be possible in this area to compare actual running costs and those used in RdSAP.

[29] Section C3.1 Distribution loss, C3 Heat distribution, Appendix C, SAP 2009 version 9.90

[30] Section C3.2 Energy for pumping, C3 Heat distribution, Appendix C, SAP 2009 version 9.90

[31] Table 12: Fuel prices, additional standing charges, emission factors and primary energy factors, SAP 2009 version 9.90

[32] Section C1 Distribution loss, C3 Heat distribution, Appendix C, SAP 2009 version 9.90

7 Costs and Savings

7.1 Commentary on upgrade costs

The costs currently applied across the retrofit examples are averages and are typically applied with limited variation across different house types. Scale factors are applicable on several energy improvement measures (although not necessarily significant) and landlords should be aware of this. Other factors will however also impact on local costs. These include, in particular, contract scale economics on large programmes of work, and geographical factors which impact strongly in the Highlands and Islands.

Table 9 below examines the individual cost bases used in the original retrofit examples and provides typical costs from social housing activity. SPONS (2013) „Rates and Costs‟ has also been examined and applied where available and appropriate. Table 9 shows that the costs applied for individual energy efficiency measures are, in general, accurate averages of actual costs currently incurred across the social housing sector. The exception to agreement with the Consultation document‟s average costs is condensing gas boilers where the current cost base of £2,500 applied to the retrofit examples is, in the view of David Adamson, high. Recent examples of social landlords‟ heating improvement work which David Adamson has examined indicate boiler costs in the range £1,600-£1,900. (SPONS (2013) indicates boiler rates as low as £630, although we have not encountered rates as low as this in the improvement work that we have examined). The costs for microgeneration systems are also in some cases open to question; this is addressed further down this page.

ENERGY MEASURE	SCALE DEPENDENCY	RETROFIT EXAMPLE COST	TYPICAL[33] CURRENT COST	COMMENTS
1. Solid Wall Insulation	Yes	£5,500	£5,160	Typical current costs are based on external insulated render (in this example 60mm Phenolic Foam Board plus render, U-value 0.30). Additional scaffolding costs will apply ranging from £2,800 in a mid-terrace configuration to £5,600 in detached configurations. 3-storey height assumed.
2. Cavity Wall Insulation	Yes	£500	£318	Typical current costs are based on 70m^2 area assuming cavity is 70 - 100mm wide. Where a cherry picker hire is required an additional to this cost at £600 per week and based on contractor installing 200m^2 CWI per day. This will raise the average current cost to approx.

[33] Typical current costs are approximate and based on 3 apt. flat (2 bedrooms and 1 lounge).

				£518. Where cavity wall insulation extract and refill is involved costs are generally 4x the cost of standard CWI fill.
3. Loft Insulation	Yes	£500	£450	Typical current costs assume $60m^2$ coverage with no insulation or less than 50mm existing in loft.
4. Loft Insulation Top-up	Yes	£283	£416	Typical current costs assume $72m^2$ coverage adding 150mm to existing 150mm coverage. Retrofit example costs make no reference to additional thickness.
5. Floor Insulation	Yes	£1,200	(i)£600 (ii)£1,200	(i) $50m^2$ - 150mm mineral wool hung in net between floor joists (U-value 0.30). (ii) $50m^2$ - 150mm solid insulated board fitted between floor joists (U-value 0.15).
6. Heating Controls	Partial	£300	Unspecified	Cannot specify current costs as the nature of the heating controls remains unspecified within the retrofit examples.
7. Condensing Boiler	No	£2,500	£1,600 - £1,900	Typical current costs are based on recent RSL experience in Govan and Clyde Valley with price variations reflecting boiler quality. SPONS 2013 total rate costs for a Potterton Performa or equivalent gas/oil boiler are as low as £630. Central heating distribution costs will typically add £1,280.
8. Double/ Secondary Glazing	Yes	£3,700 (£450 per window)	£450 - £550 per window	Typical current costs allow for UPVC frame with standard low E 24mm double glazing. Unit costs can vary substantially by contract size.
9. Solid Wall Internal Insulation	Yes	No Retrofit Example Cost Provided	£3,800	$50m^2$. 42.5mm insulated board + 12.5mm plasterboard (u-value 0.46).
10. Additional Measures **i. Biomass** **ii. SHW** **iii. PV** **iv. GSHP** **v. ASHP** **vi. Micro-CHP** **vii. Wind Turbine**	 No	 £9,000 £4,000 £8,000 £10,000 £8,400 £4,500 £8,000	 SEE NOTES ABOVE	Costs are highly dependent on system size and specification and whether distribution systems are included for heat pumps and boilers. See comments above.
11. CFLs	Yes	£15 - 3 rooms £18 - 4 rooms	£12 - 3 rooms £16 - 4 rooms	Current costs are reducing but retrofit example costs remain typical.

Table 9: Cost commentary summary review

The costs in table 9 can also be applied to the range of harder-to-treat retrofit examples (see Section 5), where the cost of many improvement options are similar to those applied across the general housing stock in. One of the most significant issues in the harder-to-treat sector is solid wall construction, where improvement costs will increase significantly through the need to over-clad as opposed to cavity fill. Table 10 shows costs for more ambitious and complicated communal improvements such as district heating and over cladding of large multi-storey flats.

Stock type	Retrofit details	Net cost	Cost per unit
9-storey block, 204 dwellings	Installation of communal gas heating system with new energy centre (central plant room) installed within existing structure	£825,000	£4,000
Two 15-storey blocks, 172 dwellings	Installation of communal gas heating system and construction of new energy centre	£2.1m	£12,200
As above	External cladding and associated structural works	£4.1m	£23,800

Table 10: cost Commentary summary review system built housing

With regard to the microgeneration measures, it is more difficult to validate these costs as they are more subject to changes in the short to medium term: e.g. PV costs have dropped radically in recent years since the FIT scheme was introduced; the RHI may or may not have a similar effect on some of the heat-generating technologies. Measures also come in many different sizes and some will have greater associated costs than others, which will inevitably affect overall costs. Without specifications, it is hard to establish the accuracy of these costs. The following observations can be made, however:

- If the biomass system refers to a biomass boiler, the quoted cost would appear lower than average. In any case, however, it seems more likely that social landlords would consider biomass primarily in terms of communal heating systems, rather than individual boilers or stoves.

- PV costs continue to fall. A 4kW system may be sourced for less than £8,000 at present, however a typical social housing PV installation is more likely to be 2.5-3kW, which will be cheaper again: £5-6,000 is possible. Costs are likely to continue to fall for this technology.

- The GSHP cost seems low; costs are more likely to range between £12-15,000.

- Some social landlords have installed ASHPs for less than the quoted figure.

- Micro-CHP currently has very limited take-up; its relevance to meeting future standards is therefore uncertain.

- It is unclear what size of wind turbine this cost refers to; very small-scale building-mounted turbines should cost less than this but these are rarely specified in social housing. More typical domestic turbines (e.g. 6kW) may cost closer to £25-30,000 per unit. However, installation of small-scale wind turbines by social landlords is currently limited; if wind is under consideration it seems to be more common for the focus to turn to larger-scale turbines – which are likely to fall outside the remit of the standard.

- For all renewable energy systems, some level of specification should be included in the final standard to put the suggested costs in context. In particular „micro wind" should be defined, as definitions vary and wind turbines can vary considerably in size and power and still be deemed small.

Communal systems have not been included in the retrofit examples, however brief discussion of these is useful to provide a comparator, as larger-scale retrofit projects are often preferred by landlords for a variety of reasons. Costs in table 10, taken from 2012 retrofit projects of non-traditional social housing blocks in Edinburgh, illustrate the potential financial outlay that may be expected. These are specific examples that are useful indicators for social landlords considering similar large-scale improvements. They also serve to highlight the importance that plant room location has in determining costs; if it can be absorbed into the existing structure this is likely to save significant amounts and result in a more cost-effective system.

7.2 Costs and savings

Energy and CO_2 savings for the different property types are provided within the individual retrofit examples. At the Scottish Government"s request, these predicted savings were aggregated across the Scottish social housing stock, to provide an indicator of the potential impact of complying with the EESSH (using the SHQS as a baseline).

As with any aggregated projections, these figures come with a number of caveats. To extrapolate the results of a small number of retrofit examples to a larger number of dwellings across the stock (such as the 645,000 homes in the Scottish social housing sector) relies on several assumptions, and for a full stock model analysis, significantly more than 35 example buildings should be used. Therefore, the aggregated results of this study are designed to be indicative estimates of the potential CO_2 reductions, energy savings and refurbishment costs that might be expected for the Scottish social housing sector to meet the EESSH.

7.3 Aggregated figures and assumptions

All savings are shown in the table 11, and refer to the measures required to meet the EESSH that are *additional* to meeting the SHQS; therefore, for those retrofit examples that already reach the EESSH by virtue of reaching the SHQS, there are no additional measures (or costs). It should be noted that, for thirteen property types (12 of which are electric), applying the original list of „further" measures by 2020 was not sufficient for them to meet the proposed ratings. If these were not retrofitted to the same standard as the other example properties, this would reduce the CO_2 savings and capital costs.

Subject to the described approximations, the results suggest that the additional capital cost of reaching the EESSH (from an SHQS baseline) would be in the region of £2.2bn across the stock. This cost is split between the chosen measures as follows:

- Condensing boilers (43% of total cost)
- Double/secondary glazing (24%)
- Heating controls (5%)
- Storage heaters (4%)
- Loft insulation top up (3%)
- Floor insulation (1%)
- Compact fluorescent lighting (less than 0.5%).
- External wall insulation (19.5%)

In terms of impact, the £2.2bn cost would save a total 4,387GWh/yr of primary energy (see note below concerning primary energy), equivalent to 839,263 tonnes of CO2 per year. Refurbishing to this level thus costs £2.66 per kgCO2 annually saved..

These figures are subject to the following assumptions and caveats:

- Savings for the retrofit example dwellings refer to gas or electric-heated versions. The savings for electric-heated dwellings have been approximated for all non-gas heated dwellings; this is a limitation of the size of the sample used. It is assumed, based on Scottish averages, that 67% of homes have mains gas heating,[34] but these homes are not evenly distributed. This ratio is used for each typology when weighting the savings;
- Disaggregation of the Scottish social housing stock is restricted to the retrofit examples used. The effects of orientation, wall/floor/glazing/roof type, micro-climate etc. are not accounted for;
- All savings are based on SAP modelling exercises of the retrofit examples and should be treated as such;
- The savings use SHQS as a baseline, so all calculations relate to the effect of meeting the enhanced EESSH (where achieved)
- Not all retrofit examples were actually retrofitted in this aggregation exercise:

[34] Assessing the impact of the central heating programme on tackling fuel poverty: report on the first year 2001 – 2002, Scottish Government 2004

- 57 examples were retrofitted (applying the 2020 „further" measures):
  - 53 met the EESSH
  - 4 will not reach the proposed ratings (of these, 1 would, if the „advanced" measures were applied, but three would still not reach the proposed ratings)
- 9 examples were not refurbished:
  - None already met the proposed ratings by virtue of having met the SHQS
  - For all 9 examples, no 2020 „further" measures where suitable. However, eight would meet the proposed ratings if the „advanced" measures were applied

- All energy savings (kWh) refer to primary energy, in accordance with the headline figures given with current Energy Performance Certificates (EPCs). This is, in effect, the energy used at production (i.e. power plant) level, not that used at secondary (i.e. householder) level. Primary energy consumption figures will be higher as they include all the distribution and production losses of energy, as well as that consumed by end users. **These figures should therefore not be confused with domestic consumption figures that households and landlords might be more familiar with, from billing information.** For example, in accordance with SAP/RdSAP guidance, 1kWh of „secondary" electrical consumption is equivalent to 2.9kWh of „primary" energy consumption. Likewise, 1kWh of secondary gas consumption is equivalent to 1.02 kWh of primary gas consumption. Standard CO_2 intensity factors ($kgCO_2/kWh$) are usually applied to secondary energy values.

7.4. Validation

In order to cross-reference these projections, the above figures were compared to a recently-published report from WWF Scotland[35]. This report sought to assess the resources needed to deliver a 42% saving across the entire Scottish housing stock, using a consultant"s (Verco) in-house modelling tool, capital costs from the Energy Saving Trust and CO_2 savings derived from SAP 2005. A number of other assumptions were different from our analysis, for instance a greater focus on lower-cost measures, most of which are already delivered in social housing through the SHQS. The WWF study established costs ranging from £6.3-9.4bn for the entire stock. Based on a pro-rata share of 27% for social housing, this would give a corresponding range of £1.7-2.5bn (in comparison to the £2.2bn calculated for this Peer Review).

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[35] *Mind The Gap: Funding home energy efficiency to deliver Scotland's climate change and fuel poverty targets* (WWF Scotland, 2012)

7.5 Recommended approach for harder-to-treat stock

Based on the phasing of measures in the consultations, some stock types (e.g. multi-storey flats, external deck access flats) did not originally meet the proposed ratings through „further" measures. To reach the proposed ratings, „advanced" measures such as solid wall insulation and double glazing are required. As part of the validation exercise, measures such as solid wall insulation, were Modelled. Together with hard-to-treat cavity wall insulation, solid wall insulation in particular is likely to be specified by social landlords in advance of 2020: it is an established technique (particularly externally for multi blocks, which also tend to be in sole or majority ownership of the landlord), there will be funding available through ECO, such housing is likely to be attractive to energy companies to fund and these homes need to be affordable to inhabit. (Some traditional tenements will also not meet the proposed ratings , however these are likely to require different upgrade measures and have more mixed-tenure and consent issues.) Furthermore, some internal wall insulation measures, favoured by Historic Scotland in terms of breathability are below the specified U-value needed to secure ECO.

As part of the validation process, inclusion of external solid wall insulation was noted, as a means by which the vast bulk of these property types can reach the proposed ratings. However without subsidy support, these measures may not always be cost-effective. In this regard ECO funding should be available for most solid wall insulation systems. There are however uncertainties over the price per tonne of CO_2 saved, and whether social landlords will have to meet some of the costs. If funding wasn"t available at an appropriate level to facilitate improvements, some property types will be unable to achieve the proposed ratings in EESSH. If issues of affordability were to arise it might be necessary to treat these buildings as a single group contributing towards meeting the standard and efforts to reduce the sectors overall carbon emissions.

It is argued that using the EESSH should be designed to drive forward the retrofit of system-built and high-rise properties drawing down on ECO funding. Cladding these poorly performing properties with EWI will not only impact positively on achieving CO_2 targets but also help to address concentrations of fuel poverty. It should be noted that the Housing (Scotland) Act 2001 sets a statutory duty on the Scottish Government to eradicate fuel poverty in Scotland, as far as is reasonably practicable by November 2016. In this context the Scottish Government needs to demonstrate that tackling these properties is not reasonably practical either on cost or technical grounds. What is practical will vary between buildings: therefore it is recommended that as part of the EESSH, landlords should demonstrate what practical steps have been taken to minimise tenants" fuel costs, including a full investigation of external wall insulation options.

In terms of what is practical there is strong evidence from the former Community Energy Saving Programme (CESP) that energy companies will target properties a) with potentially high CO_2 savings from EWI and b) where they can work with social landlords to manage improvements rather than tackling multiple private households. If projects were deprioritised there is no guarantee that today"s level of funding and low costs of borrowing will be available in the future.

Retrofit Examples	Primary Energy savings (MWh/yr)			Carbon Savings (tCO2/yr)			Total no. in typology	Cost of retrofit (£)			Cost of retrofitting typology (£M)	Refurbished? (Y/N)		Was EESSH met by 2020? (Y/N)	
	Gas	Other	Weighted	Gas	Other	Weighted		Gas	Other	Weighted		Gas	Other	Gas	Other
A1 - Pre 1919 solid wall flat - GF	7.7	0.0	**5.1**	1.5	0.0	**1.0**	14,000	£2,800	£0	**£1,848**	**£26 M**	Y	N	Y	Y
A2 - Pre 1919 solid wall flat - MF	6.2	0.0	**4.1**	1.3	0.0	**0.8**	13,000	£2,800	£0	**£1,848**	**£24 M**	Y	N	N	N
A3 - Pre 1919 solid wall flat - TF	7.9	6.3	**7.4**	1.5	1.1	**1.4**	8,000	£3,083	£3,983	**£3,389**	**£27 M**	Y	Y	Y	Y
B4 - Interwar cavity flat	7.3	1.4	**5.3**	1.4	0.3	**1.0**	25,000	£6,500	£1,050	**£4,647**	**£116 M**	Y	Y	Y	Y
B5 - Interwar cavity house - mid-terr	8.6	0.0	**5.7**	1.7	0.0	**1.1**	8,000	£3,083	£0	**£2,035**	**£16 M**	Y	N	Y	Y
B6 - Interwar house - semi-detached	10.4	0.0	**6.9**	2.0	0.0	**1.3**	28,000	£3,083	£0	**£2,035**	**£57 M**	Y	N	Y	N
C7 - Four-in-a-block - lower	9.4	3.7	**7.5**	1.8	0.7	**1.4**	58,000	£2,800	£1,200	**£2,256**	**£131 M**	Y	Y	Y	Y
C8 - Four-in-a-block - upper	10.0	2.8	**7.5**	1.9	0.5	**1.4**	38,000	£3,083	£1,050	**£2,392**	**£91 M**	Y	Y	Y	Y
D9 - Post-war flat 1950-64	5.8	7.4	**6.4**	1.1	1.3	**1.2**	58,000	£2,800	£4,750	**£3,463**	**£201 M**	Y	Y	Y	Y
D10 - Post-war 1950-64 - mid-terr	8.1	0.0	**5.4**	1.5	0.0	**1.0**	24,000	£3,083	£0	**£2,035**	**£49 M**	Y	N	Y	N
D11 - Post-war 1950-64 - semi-detached	11.2	0.0	**7.4**	2.2	0.0	**1.4**	55,000	£3,083	£0	**£2,035**	**£112 M**	Y	N	Y	N
E12 - 1965-83 flat	6.0	5.0	**5.7**	1.1	0.8	**1.0**	45,000	£6,500	£4,750	**£5,905**	**£266 M**	Y	Y	Y	Y
E13 - 1965-83 - mid-terr	12.7	1.4	**8.9**	2.5	0.3	**1.7**	38,000	£6,783	£283	**£4,573**	**£174 M**	Y	Y	Y	N
E14 - 1965-83 - semi-detached	11.4	0.0	**7.6**	2.3	0.0	**1.5**	43,000	£3,083	£0	**£2,035**	**£87 M**	Y	N	Y	N
*F15 - 1984-91 flat**	5.3	1.2	**3.9**	1.0	0.2	**0.8**	14,000	£6,515	£1,065	**£4,662**	**£65 M**	Y	Y	Y	Y
*F16 - 1984-91 - mid-terr***	10.2	0.0	**6.7**	2.0	0.0	**1.3**	4,000	£6,798	£0	**£4,487**	**£18 M**	Y	N	Y	N
*F17 - 1984-91 - semi-detached***	11.6	1.8	**8.3**	2.2	0.4	**1.6**	5,000	£6,798	£3,700	**£5,745**	**£29 M**	Y	Y	Y	N
G18 - 1992-98 flat	6.2	2.3	**4.9**	1.2	0.4	**0.9**	13,000	£6,515	£4,765	**£5,920**	**£77 M**	Y	Y	Y	N
G19 - 1992-98 - mid-terr	5.9	3.1	**5.0**	1.1	0.6	**1.0**	5,000	£3,098	£4,750	**£3,660**	**£18 M**	Y	Y	Y	Y
G20 - 1992-98 - semi-detached	6.8	3.5	**5.7**	1.3	0.6	**1.1**	3,000	£3,098	£4,750	**£3,660**	**£11 M**	Y	Y	Y	Y
H21 - 1999-present flat	1.5	1.1	**1.4**	0.3	0.2	**0.2**	17,000	£2,815	£1,065	**£2,220**	**£38 M**	Y	Y	Y	Y
H22 - 1999-present - mid-terr	2.7	1.8	**2.4**	0.6	0.4	**0.5**	5,000	£3,101	£1,351	**£2,506**	**£13 M**	Y	Y	Y	Y
H23 - 1999-2007 - semi-detached	2.6	1.6	**2.2**	0.4	0.3	**0.4**	6,000	£3,101	£1,351	**£2,506**	**£15 M**	Y	Y	Y	Y
HTT3&4 - High rise	4.7	9.8	**6.4**	0.9	1.8	**1.2**	36,000	£5,500	£5,500	**£5,500**	**£198 M**	Y	Y	Y	Y
*HTT5&6- Hi rise deck access flat****	12.0	11.6	**11.9**	2.4	2.1	**2.2**	12,000	£5,500	£5,500	**£5,500**	**£66 M**	Y	Y	Y	Y
*HTT7&8 - Concrete Flats****	11.6	8.6	**10.5**	2.3	1.6	**2.0**	16,000	£8,457	£5,642	**£7,499**	**£120 M**	Y	Y	Y	N
HTT11 - Concrete Semi	8.5	20.1	**12.5**	1.7	3.9	**2.4**	7,000	£5,783	£5,500	**£5,687**	**£40 M**	Y	Y	Y	Y
HTT9 - Timber frame semi - pre-1950	17.1	12.7	**15.6**	3.3	2.2	**2.9**	3,000	£8,583	£5,500	**£7,535**	**£23 M**	Y	Y	Y	Y
HTT10 - Timber frame semi - post-1950	11.1	0.0	**7.3**	2.1	0.0	**1.4**	17,000	£3,083	£0	**£2,035**	**£35 M**	Y	N	Y	N
HTT12 - Steel frame semi	7.9	20.6	**12.2**	1.6	3.7	**2.3**	6,000	£5,783	£5,500	**£5,687**	**£34 M**	Y	y	Y	Y
Other	8.3	4.3	**6.9**	1.6	0.8	**1.3**	21,000	£3,382	£1,328	**£2,684**	**£56 M**				
TOTAL			**4,387,233**			**839,263**	**645,000**				**£2232 M**				

Table 11 Aggregated Cost of Retrofitting from SHQS to EESSH
*Energy and CO_2 savings calculated relative to 'Baseline' where this was already in line with 'SHQS 2015' requirements (i.e. no measures required prior to EESSH improvements)
**Gas energy and CO_2 savings calculated relative to 'Baseline' where this was already in line with 'SHQS 2015' requirements (i.e. no measures required prior to EESSH improvements)
*** Values reported represent the average of multiple example dwellings described by this typology

8 Feasibility and Risks

This section comments on the technical, financial and organisational reasonableness and risks to landlords of meeting the proposed standard as set out in the consultation document. Other related issues are also considered.

8.1 Overview of use and applicability of measures

This brief section draws on David Adamson‟s recent experience working with social landlords and local authorities in Scotland on costing and delivering housing stock upgrades both for energy efficiency and SHQS purposes.

A broad range of measures is applied across the retrofit examples, not all of which would be typically applied by social landlords in Scotland.

Typically, applied measures in David Adamson‟s experience are as follows:

a. Insulation

- Loft insulation: virgin (first time installation) and „top-up‟
- Cavity wall insulation
- External wall applied insulation
- Tank and pipe insulation (loft)
- Hot water cylinder insulation
- Double glazing
- Draught-proofing

Additional insulation measures applied in some of the retrofit examples include floor insulation and internal insulation. David Adamson found limited evidence of the application of these measures across Scotland, largely due to tenant disruption on application (this is referred to in section 3). Double glazing now also tends to be a less than typical measure, due to high levels of existing double glazing in social housing in Scotland.

b. Heating

- Heating system replacement (typically electric)
- Boiler replacement

- Electrical wet system
- Controls upgrade (typically TRVs and room thermostats)

David Adamson confirmed recent social landlord experience is dominated by boiler replacement and whole-system replacement, particularly in the movement away from electrical heating systems. Electrical wet systems are also becoming more common. Heating solutions within the social rented sector are, in our experience, dominated by SHQS requirements (particularly SAP ratings) which are heavily influenced by boiler and fuel efficiency. Limited programmes targeted at heating control improvements were identified; these would typically be addressed during broader programmes of boiler or whole-system replacements.

c. Additional measures

Additional measures recorded across the retrofit examples include PV and CFLs. David Adamson has found limited application of PV technology in social housing across Scotland, with limited inclusion in improvement strategies, although this is changing with the development of the FIT and other financial incentives. Consideration is more often made by social landlords where housing stock is off the gas network or harder-to-treat. The installation of CFLs in social housing tends to be tenant driven, and not integral to improvement policies.

8.2 Technical feasibility and risks

Technical risks relate to individual property types and may be influenced both by construction type and previous maintenance. In most cases the measures proposed in the consultation document and examples present few technical risks with correct assessment and installation. The key exceptions tend to be solid wall insulation[36], either internally where issues of condensation and associated problems could arise, or where there are previous structural issues with the design and construction of the building (e.g. Orlits). There are also cases of external wall insulation trapping moisture, although these are rarer. Solid wall insulation is a particularly important area at present given its focus in the Green Deal and ECO. Landlords are likely to come under increasing pressure to address solid walls; however there are opposing views of how such walls should be treated (materials, methods, systems)[37]. The ensuing confusion could lead to a risk of a „do-nothing‟ approach in some cases.

Internal wall insulation may be avoided due to the need to decant tenants from properties. This leads to disruption for tenants and challenges in finding suitable alternative accommodation. However, external wall insulation is not always suitable, usually for reasons of appearance or the multi-tenure nature of a building, and this leaves internal insulation as the only option to address heat loss through the walls.

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[36] *Solid wall insulation in Scotland – Exploring barriers, solutions and new approaches* (Changeworks, 2012)

[37] *Ibid*

Further exploration of the solutions to these issues is necessary if the standard is to be met for all properties.

As highlighted both in this report and the consultation responses, there is a risk that some relatively high-performing properties or measures may find it more difficult to meet the standard. The reasons centre on the assumptions within RdSAP and how well or poorly they represent certain measures. Some measures show no or minimal savings because they are given a default efficiency that cannot be over-ridden even if the manufacturer states an efficiency superior to the default. In other cases the fuel costs in RdSAP will be higher than for local fuels such as wood chips. For this reason some properties will find it more difficult to meet one or other of the two ratings (EE and EI). This is particularly significant for off-gas properties that may struggle to reach the required EI rating on account of emissions, or where biomass boilers register a low EE rating on account of cost. It is noted however than the EESSH sets a lower threshold for off-gas properties.

Certain microgeneration systems carry technical risks, related not only to the property and installation but also to the user interaction. Unlike passive improvement measures (e.g. insulation) many renewable energy systems require active participation and understanding to realise their potential (e.g. heat pumps, PV, solar thermal). In some cases this can be particularly problematic[38] and additional resources are required to support both tenants and landlords – which will have associated costs. Systems such as heat pumps are also reliant to a certain degree on the efficiency of the property and the distribution system (CO_2 and cost savings from a heat pump could vary considerably between a poorly-insulated property with radiators and a well-insulated property with under-floor heating). This means that either considerable additional works may be required, or the technology may not be selected for installation.

Listing of historic properties does not mean they cannot be improved, but it may require particular technical solutions. While these are technically feasible, the main problem is one of cost; this is covered in the section 7. This can also present issues in terms of landlords" knowledge of energy efficiency as this varies. For listed buildings and properties in conservation areas, the solutions are often deemed relatively niche and some landlords may not be aware of the retrofit options available.

8.3 Cost and funding issues

8.3.1 Harder-to-treat properties

Particularly for harder-to-treat properties, some social landlords may struggle to afford the more expensive improvement measures needed to bring their stock up to the standard. Upfront funding remains relatively sparse for energy upgrades, and smaller organisations with fewer resources may not have the capacity to cover the costs associated with meeting the standard.

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[38] *21st century heating in rural homes – Social landlords and tenants' experience of renewable heat* (Consumer Focus Scotland, 2012)

For mixed tenure properties, the cost of measures is a critical factor, as owner occupiers or landlords may not be able to meet their share of the costs. Whilst social landlords may be able to use legal mechanisms (enforcing title deeds or the Tenement Scotland Act 2006) to drive such works forward, in practice the time and costs of such a strategy could be prohibitive. This is a major consideration for improvements such as external wall insulation. Similarly there could be considerable „hidden‟ costs in terms of staff time for more major measures that entail lengthy tenant negotiations, plus costs for decanting tenants (and associated rent losses) where the works are deemed too disruptive to carry out with occupants *in situ*. For more invasive measures such as internal wall and floor insulation, there are also likely to be associated redecoration costs. For listed buildings, specialist measures are often required, and these tend to come at a premium. All these factors are commonly not factored into cost projections, but landlords will have to find funding to cover these costs if the works are to be completed.

8.3.2 The Green Deal and ECO

The Green Deal and ECO are the main funding streams available for energy efficiency measures, and it is hoped that social housing providers will be instrumental in the uptake of measures such as solid wall insulation, partly due to their ability to deliver improvements at scale. However, DECC‟s current proposals are complex with several important questions still not resolved, and the level of uptake in Scottish social housing difficult to predict. Early research[39] suggests uptake of the Green Deal may be limited, partly due to a range of concerns, for example that tenants would not realise the „golden rule‟ because they under-heat their homes. Furthermore, as the Green Deal is a long-term debt on the property, future tenants who move into the property will adopt the Green Deal. If they have a different number of occupants or different lifestyles, they may be unable to achieve the energy savings previous tenants were using to meet their Green deal payments.

With regard to the Carbon Emissions Reduction Obligation (CERO) of ECO, this could also pose problems where solid or harder-to-treat cavity wall insulation is a required measure to access the subsidy: not all properties are suited to external insulation and consultation responses highlighted the likelihood of some tenant refusals of internal insulation due to the disruption involved. This means that where solid wall insulation is not felt feasible, funding will not be available for other measures under this obligation.

Other measures are available through the Affordable Warmth Obligation of ECO but social landlords are not eligible for this. However, where the social landlords‟ property is in a rural settlement of less than 10,000 houses or located in or near a datazone in the worst 15% of the Scottish Index of Multiple Deprivation (SIMD), as measures may then qualify for the Carbon Saving Communities Obligations (CSCO) of ECO. However, even in these areas social landlords will be unable to attract any support from ECO for fuel switching and new boilers (previously, such subsidies were available under industry programmes such as CERT and CESP especially where electric heating

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[39] *Renewable Energy: Getting the benefits right for social housing* (Changeworks on behalf of the Joseph Rowntree Foundation, 2012)

has been replaced). In future, without such subsidies, fewer similar projects may progress. A modified DECC table 12[40] is included below to illustrate the eligibility criteria of different measures.

GREEN DEAL MEASURES (Key: Green: Always eligible Blue: Eligible when delivered as part of a package with solid or hard-to-treat cavity wall insulation Red: Never eligible)	**In ECO Carbon Reduction** (All households)	**In ECO Carbon Saving Communities** (Homes in defined low-income areas)
Air source heat pumps	N	N
Biomass boilers	N	N
Biomass room heaters (including with radiators)	N	N
Cavity wall insulation	P	Y
Cavity wall insulation (HTT)	Y	Y
Cylinder thermostats	N	N
District heating (not GD)	P	Y (if has LI or CWI)
Draught proofing	P	Y
Duct insulation	N	N
Hot water showers (efficient)	N	N
Hot water systems (efficient)	N	N
Hot water taps (efficient)	N	N
External wall insulation systems	Y	Y
Fan-assisted replacement storage heaters	N	N
Flue gas heat recovery devices	N	N
Ground source heat pumps	N	N
Heating controls (for wet central heating system and warm air system)	N	N
Heating ventilation and air-conditioning controls (including zoning controls)	N	N
High performance external doors	P	Y
Hot water controls (including timers and temperature control)	N	N
Hot water cylinder insulation	N	N
Internal wall insulation (of external walls) systems	Y	Y
Lighting systems fittings and controls (including rooflights lamps and luminaires)	N	N
Loft or rafter insulation (including	P	Y

[40] *Which energy efficiency improvements qualify for Green Deal finance?* (DECC, 2012). This table has been modified by removing the Affordable Warmth stream as social landlords are not eligible for this.

loft hatch insulation)		
Mechanical ventilation with heat recovery	N	N
Micro combined heat and power	N	N
Micro wind generation	N	N
Pipe-work insulation	(external only)	(external only)
Photovoltaics	N	N
Chillers	N	N
Gas-fired condensing boilers	N	N
Replacement glazing	P	Y
Oil-fired condensing boilers	N	N
Warm-air units	N	N
Radiant heating	N	N
Roof insulation	P	Y
Room in roof insulation	P	Y
Sealing improvements (including duct sealing)	N	N
Secondary glazing	P	Y
Solar water heating	N	N
Solar blinds shutters and shading devices	N	N
Transpired solar collectors	N	N
Under-floor heating	N	N
Under-floor insulation	P	Y
Variable speed drives for fans and pumps	N	N
Waste water heat recovery devices attached to showers	N	N
Water source heat pumps	N	N

Table 12: ECO eligible measures

External solid wall insulation is recommended as a „Further Measure 2020" for the following 18 property types:

1. HTT-3E: System built Multi-storey flat 1950-64 - ground floor gable end (2 bed)
2. HTT-3G: System built Multi-storey flat 1950-64 - ground floor gable end (electric - gas community heating) (2 bed)
3. HTT-4E: System built Multi-storey flat 1950-64 - mid floor gable end (2 bed)
4. HTT-4G: System built Multi-storey flat 1950-64 - mid floor gable end (electric - gas community heating) (2 bed)
5. HTT-5E: 1950-64 System built external deck access flat, ground floor gable end (2 bed)
6. HTT-5G: 1950-64 System built external deck access flat, ground floor gable end (2 bed)
7. HTT-6E: 1950-64 System built external deck access flat, mid floor gable end (2 bed)
8. HTT-6G: 1950-64 System built external deck access flat, mid floor gable end (2 bed)
9. HTT-7E: No Fines concrete flat (2 bed) - ground floor, gable end (both user defined U-values and default examples)
10. HTT-7G: No Fines concrete flat (2 bed) - ground floor, gable end (both user defined U-values and default examples)
11. HTT-8E: No Fines concrete flat (2 bed) - top floor, gable end (both user defined U-values and default examples)

12. HTT-8G: No Fines concrete flat (2 bed) - top floor, gable end (both user defined U-values and default examples)
13. HTT-9E: Swedish timer frame semi-detached (3 bed - 1946) (both user defined U-values and default examples)
14. HTT-9G: Swedish timer frame semi-detached (3 bed - 1946) (both user defined U-values and default examples)
15. HTT-11E: System built house concrete house (Orlit - 3 bed - 1930-49)
16. HTT-11G: System built house concrete house (Orlit - 3 bed - 1930-49)
17. HTT-12E: System built house steel house (BISF - 3 bed - 1930-49)
18. HTT-12G: System built house steel house (BISF - 3 bed - 1930-49)

For these property types the Scottish Government should assist social landlords in developing programmes aimed at securing ECO funding.

8.3.3 FITs & RHI

The introduction of the FIT triggered an increase in the uptake of electricity-generating technologies, predominantly small-scale PV (any wind or hydro installations for social housing are likely to be larger scale). The generous FIT rates for PV led to a rush to install the technology (in some cases more for the financial than the environmental or fuel bill benefits). Unfortunately the recent FIT cuts (not only cutting the overall rates, but implementing a further-reduced rate for multiple installations) has in many cases led to a suspicion of the scheme amongst social housing providers, and in some cases an assumption that the scheme is no longer beneficial[41]. This may cause a temporary stall in the installation of PV in social housing (although current research[42] aims to rectify this situation and highlight the benefits both to tenants and landlords, and provide guidance to support its installation and use).

The domestic stream of the RHI is due to be implemented in spring 2014. If they are eligible and the tariff is sufficiently generous, this is likely to trigger considerable interest among social landlords, particularly those with stock in off-gas areas. This may lead to an increased uptake of heat-generating technologies (heat pumps, biomass systems and solar thermal). It should be noted, however, that social landlords" eligibility and/or tariff levels are not yet confirmed[43].

The FIT has led to considerable cost reductions for technologies such as PV, making it a more viable consideration for social landlords despite the FIT reductions. The same may occur to a degree with the RHI. However, incentive rates are being strategically depressed by DECC over time and while the openness of these reductions provides more certainty for investors, this could still make funding some renewable energy systems financially challenging.

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[41] *Renewable Energy: Getting the benefits right for social housing* (Changeworks on behalf of the Joseph Rowntree Foundation, 2012)

[42] *Using solar PV to tackle fuel poverty* (Changeworks, pending, 2013)

[43] *Renewable Heat Incentive: Consultation on proposals for a domestic scheme* (DECC, 2012)

8.4 Organisational practicality and risks

Legal issues surrounding right-to-buy properties, communal roofs and rent-a-roof PV schemes are other factors which can hinder the roll-out of certain measures, in particular advanced measures such as solar systems (PV and solar thermal). Right-to-buy owners may not have the capital to contribute to whole-block improvements, and enforcing mixed-tenure retrofits is likely to be time-consuming and carry a financial cost. Installing solar panels on shared roofs carries numerous legal complexities, as ownership, maintenance responsibilities, legal liabilities and so on would all require clear establishment; this presents a major barrier to mixed-tenure solar installations. Other issues such as equity (in terms of who benefits from the renewable energy and any associated income) also come into play. On a related note, while rent-a-roof schemes for PV are becoming less common, they can cause legal complexities related to mortgages and sales of properties in the future.

Social landlords" scope to borrow for improvements varies considerably. Many will have existing covenants with lenders that will be hard to extend or renew at the rates available in the early 2000s. This will constrain the scope to accelerate their capital programmes or roll-out significant improvements. Social landlords also face uncertainty over future revenue streams due to reforms to tenants" benefits payments, and fears about increased arrears. Depressed rental income streams will further hinder the scope to borrow for enhanced capital programmes

Social landlords will require appropriate guarantees regarding systems such as solid wall insulation. An equivalent guarantee scheme to CIGA (for cavity wall insulation) has now been set up, called SWIGA[44]. Measures delivered through the Green Deal or ECO will require appropriate guarantees, but these have not all yet been established.

8.5 Other observations

Estimated savings are just that – a hypothetical benefit based on a number of assumptions about the property, its occupants, the improvement measures and how they are used. An increasing body of research is highlighting the inherent risks of relying on savings predicted by RdSAP and other software tools. The Green Deal will now incorporate „in-use factors", for example, reducing the savings predicted by RdSAP in an attempt to make the projections more realistic.

Another area that could present challenges for the RdSAP methodology is ventilation heat loss (particularly in higher wind speed areas, e.g. the islands). Many social landlords report significant issues around excessive heat loss in these areas, caused by lack of airtightness around window and door openings, ground floor and soffit vents, and holes cored in the fabric for services or to provide ventilation for combustion appliances. However, the benefits of addressing these issues are not currently felt to be adequately recognised by RdSAP, and so there may be little incentive to address these issues effectively.

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[44] www.swiga.co.uk

Particularly for some forms of renewable energy, landlord and tenant guidance will be fundamental if the technologies are to realise their potential savings. Again, research[45] demonstrates the under-performance of such technologies if they are used incorrectly by tenants, and landlords do not have the resources or knowledge to resolve these issues.

There is also a risk of landlords focusing primarily on meeting the standard, rather than taking a more holistic approach and doing what is best for their buildings and tenants. In some cases this could lead to landlords installing inappropriate measures just to meet the standard – and conversely not installing beneficial measures because despite being beneficial, they are not recognised by RdSAP and so do not contribute to meeting the standard.

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[45] *21st century heating in rural homes – social landlords' and tenants' experience of renewable heat* (Consumer Focus Scotland, 2012)

9 Conclusions

This document presents a thorough analysis of the EESSH consultation document, highlighting a number of areas for consideration. Elements have been validated throughout and refinements made or proposed to enhance the final standard. A number of key points stand out and these are drawn together in this concluding section.

9.1 Baseline Assumptions

Overall, the consultation makes the correct assumptions based on the data that is available. There are limits in relation to how far the 1990 baseline can truly reflect the specifications of older properties at the time. For example, it was difficult to attain specific data in relation to the likely levels of loft insulation. In some areas the review highlighted a range of alternate assumptions which if utilised could affect the theoretical baseline, if the modelling was updated or repeated. Such issues are discussed in the annex and include minor changes to the baseline assumptions for examples D (1950 to 64) and example Group G and whether additional open chimneys should be specified in (example A to D). The debate over specifying open chimneys highlights the difficulty of pinpointing a theoretical baseline in 1990. In this instance the modeller could either enter the results as built (e.g. open coal fires) or decide that open chimneys are likely to be sealed in a gas heated property with a flue.

It is also probable that some of the older property examples as built would have had less tank insulation than the baseline assumption. This issue was modelled separately, and it was found that it had neither a significant impact on the baseline or implications for strategies associated with meeting the SHQS and EESSH. Given this minor impact it deemed unnecessary to revise the modelling.

9.2 Representation of the social housing stock

The consultation charts a pathway through to 2020 and beyond toward 2050 climate change targets for 23 retrofit examples. These 23 examples represent a cross-section of the Scottish housing stock and are a useful reference point for social landlords. However, the Peer Review identified some gaps in the mix of examples versus the profile of the Scottish housing stock in terms of different age bands corresponding to building standards identified by RdSAP. The Scottish Government had noted issues of coverage when commissioning the Peer Review. To address this, a further twelve harder-to-treat properties have been provided which fit the profile of the Scottish social housing stock. These provide a good cross-section of harder-to-treat property types. Each was modelled with gas and electric heating. At this stage in the validation exercise the latest and most up-to-date version of RdSAP was available (RdSAP 2009 (v9.91).

9.3 Remodelling and validation

Each of the 23 examples was first modelled using RdSAP 2009 (v9.90), the most up-to-date version available at the time. When reviewing the examples, the input assumptions were deemed valid. As noted above, for some retrofit examples it would be valid to consider alternate values for loft insulation, tank insulation and number of open chimneys for the baseline. Inputting alternate values alters the percentage improvement but does not alter the path to SHQS compliance (This is discussed further in the Report Annex A). On account of the limited data on loft insulation levels, it was felt reasonable to specify 100mm as per the SHQS minimum standard. In practice, any installs later in this period would be 250mm, to meet the minimum U-value in building standards. This again does not significantly change the path to achieving the SHQS or EESSH but does mean additional costs for top-up loft insulation, as opposed to a single installation.

9.4 Significance of software version

The remodelling resulted in some significant changes from the consultation document. As the original assumptions were deemed to be valid and were not altered, the variance is solely down to differences between RdSAP 2005 and RdSAP 2009 (v9.90). This was most pronounced in the electrically heated examples. For gas heated properties the variation was less pronounced but could be significant for some examples. In part, this is likely due to changes to the default boiler efficiencies in SAP. Where defaults are chosen, it is not anticipated that there will be significant variations between version 9.90 and 9.91. Care should be taken when comparing historic data from older versions of the software.

9.4.1 Utilising new RdSAP capabilities

The new version of RdSAP gives considerably more functionality and flexibility with the ability to override defaults and input user defined values. These capabilities were tested out on two examples: a Swedish timber house and a pre-1919 tenement. In the first case, the use of more property specific values rather than more generic defaults was beneficial, whilst for the latter this had a negative effect. It was noted, however, that user defined values can only be specified by a skilled assessor who can identify and evidence different specifications. In doing so, assessors should provide documentary evidence to justify the values chosen for audit purposes. The issue of evidence needs to be considered to ensure assessors can justify any in-situ U-value calculations. It will be important for social landlords to recognise this performance gap and differentiate between modelled and likely actual performance of improvement measures in relation to specific stock types and characteristics (e.g. poorly performing solid floors).

When developing the additional examples, it was noted that a number of harder to treat property types (e.g. system built and multi-blocks) did not meet the proposed ratings unless external solid wall insulation was included as a „further‟ measure rather than noted as an „advanced‟ measure (which is more applicable to the 2050 targets). New funding streams such as ECO should mean such measures will be affordable in this period, provided the specifications ensure its eligibility (e.g. U-value of 0.3 at time of writing). In this respect, the new software has advantages in providing more defaults in relation to insulation thickness, including 150mm which achieves this standard.

9.5 Communal measures

It was found that some communal measures and some draught proofing measures are not recognised adequately (if at all) by RdSAP, and so any savings made by these measures will not be accurately reflected in the ratings attributed to the property in question. Landlords must be aware of this, and recognise that while such measures may not help their stock reach in a modelled sense , in reality they are likely to benefit their tenants. Meeting a statutory obligation is a key driver for investment decisions, and this could lead to landlords installing potentially less beneficial measures to achieve compliance – and conversely not installing potentially beneficial measures because they do not contribute to the scoring system in the standard. However as noted at 6.2, the new version of RdSAP 2009 (v9.91) enables more detailed treatment of the internal corridor wall of properties (i.e. 'sheltered corridor' wall), in comparison to the previous RdSAP version (v9.90).

9.6 Feasibility and risks

The retrofit examples are intended to illustrate example routes to compliance for social landlords; they are not exhaustive either in property type or improvement measures. In most cases they use relatively simple building forms and so properties that vary from these will have different baseline performances and post-improvement impacts. Issues such as multi-tenure properties or planning restrictions on conservation-grade properties will make these harder-to-treat, and some of the common upgrade measures may not be feasible. Responsibility lies with individual landlords to identify variations and measures suitable for their own stock.

9.6.1 Solid Wall Insulation

For certain property types certain measures are likely to prove particularly complex to install. In particular, solid wall insulation where it cannot be applied externally for aesthetic or multi-tenure reasons and it cannot be applied internally for reasons of disruption or tenant refusal. Where it can be applied, subsidy in the form of ECO may not be universally available for basic measures and may only partially cover the high costs of measures such as internal wall insulation. Social landlords and the Scottish Government will need to work together to identify workable solutions to maximise levels of ECO, drawing on a limited pot of funding. A critical consideration is specifying external or internal wall insulation solutions that have a specified U-value of 0.3 (at time of writing), which equates to standards for CERO (ECO) eligibility.

9.6.2 Off-gas properties

Properties off the gas network will have lower energy efficiency and environmental impact ratings, and this has been reflected in setting a standard by fuel type. For electric properties, EE ratings are less affected due to off peak tariffs which moderate running costs. However, electric storage heating will have a low EI rating due to higher carbon emissions. Fuel switching is likely to be important where it is an option either to gas, high efficiency oil boilers or heat pumps. In some areas, consideration of the latter options is required because in future, newer forms of electric storage heating could be matched to peaks in local renewable production energy before entering the main grid.

Retaining storage heating could require more extensive fabric improvements to be considered on account of a low EI rating. Issues could arise where oil heating is the most cost effective way of boosting the EE rating or offers a better EI rating than electric storage. In the medium to long term, an electrically heated property‟s EI will improve as the grid is decarbonised. Meanwhile, low default efficiencies and higher default costs, than achieved in practice, may also reduce EE ratings for biomass systems. These issues will only be acute for a small number of properties but need to be considered by the Scottish Government on account of concerns expressed by some rural social landlords. More generally consultation responses indicated that the EE rating may be more of a focus for both landlords and tenants who are more concerned with fuel poverty.

9.6.3 Other cost and feasibility issues

In terms of feasibility, a number of key points were noted that could affect either projected impact or actual uptake of measures:

- Historic evidence shows limited application of some of the proposed improvement measures (e.g. floor insulation, internal wall insulation).

- Significant barriers are likely to include multi-tenure issues, tenant refusal of disruptive works or changes of heating system, and in conservation areas, or in Listed Buildings granting of permissions for very visible measures such as external insulation or solar panels.

- Additional costs to cover issues such as tenant decants, staff time for negotiations and use of specialist systems for harder-to-treat properties are likely to be an issue for some landlords.

- It could be hard for some properties to meet at least one of the EE and EI ratings (for example, some electric-heated properties, or those heated by biomass with its limited default efficiency rating within RdSAP). Requiring all properties to meet both EE and EI standards could prove problematic.

- Some measures, in particular certain microgeneration technologies, are likely to require time and financial investment by landlords to ensure tenants are able to use them efficiently and realise the predicted savings.

- Legal issues could present barriers to uptake of some measures, e.g. solar panels on roofs in multiple ownership, enforcing multi-tenure retrofits and Right-To-Buy owners with no funds to contribute to improvements.

- For high-rise and system-built properties, it is critical that the Scottish Government specify external wall insulation as a „further measure‟ to be included as a means to achieve the proposed ratings. This will be important in relation to fuel poverty targets and objectives as well as CO_2 targets. In some cases, technical issues may be a barrier. Cost is also a critical factor but less so if sufficient ECO subsidy can be sourced.

9.7 Costs and benefits

Costs for the retrofit examples were found to be broadly representative; however, the property details and improvement measures will clearly vary in individual cases. Some of the microgeneration costs and applicability were queried, however these costs are subject to more variation over time and this is likely to continue with the advent of further finance mechanisms such as the RHI. For communal retrofit measures, sample costs show a considerable variation, depending on aspects such as the location of any communal plant room; this is useful evidence for social landlords.

The funding arena changes periodically and this presents challenges for social landlords – but new and recent finance schemes will be of particular importance for the EESSH. Many landlords are likely to base their retrofit strategies in large part on what measures receive funding support. However, the way the FIT reductions for PV were implemented in 2011-12 has led to a degree of wariness among social landlords, and recovering from this could take some time. New schemes such as the RHI could significantly affect uptake of renewable heat systems in social housing (if it is eligible), particularly in off-gas areas. The impact of the Green Deal in social housing remains to be seen, but early research suggests eligibility and uptake may be more limited than policy-makers anticipate. Aside from EWI and hard-to-treat cavity wall insulation projects, accessing ECO will be challenging outside the worst areas of deprivation or smaller rural settlements. The best opportunities will be for solid walled properties and hard-to-treat cavities (HTTCs).

9.8 Final Summary

The assumptions in the consultation document are generally accurate and realistic. Only minor changes in approaches to modelling were identified and none were significant to warrant significant revisions in the modelled baselines or choice of retrofit measures. Timing and phasing of some measures such EWI are important if some properties are to meet the EESSH. Even for the more challenging properties, meeting the standard should not be prohibitively expensive providing ECO funding is available for external wall insulation.

Overall, the consultation retrofit examples and additional harder-to-treat examples address a wide selection of property types and show a path towards compliance. The examples fairly reflect both the limitations of the software and knowledge of the stock, particularly information on the historic baseline. Social landlords should recognise that these examples are a „best fit" and their own properties may deviate from these examples. There will, however, always be a small example of properties where compliance is challenging due to local circumstances e.g. mixed tenure or historic properties. These will require specific strategies and allowances.

10 Recommendations

The following brief recommendations are intended to assist the Scottish Government in finalising the standard, developing and expanding the approach introduced in the consultation.

Recommendations for the finalised EESSH	
1	The additional retrofit examples (section 5) should be used to demonstrate how to achieve compliance for non-standard, harder-to-treat housing stock.
2	A mechanism could be established for recognising and rewarding the installation of those measures that yield reductions in heating, emissions and fuel bills but may not be recognised by RdSAP currently (e.g. communal building area improvements). For example, giving landlords credit for investments in communal measures and leeway where properties are close to, but do not fully meet, the standard.
3	Care should be taken when using historic modelling data based on older versions of RdSAP e.g. 2005 v9.83. Where possible the latest version of RdSAP should be used when assessing the baseline for properties. RdSAP 2009 v9.91‟s additional default insulation values and flexibility to enter calculated U-values (see recommendation 4) offer social landlords additional flexibility in meeting the standard.
4	It should be made clear to social landlords installing insulation that documentary evidence should be provided and recorded if overwriting any default U-value assumptions (e.g. for floor insulation, section 3.2.4). The Scottish Government should work with DECC to collate sources of evidence for in-situ U-values common to social housing types in Scotland.
5	There could be merit in amending the loft insulation thickness (section 3.2.5) and corresponding thermal properties for retrofit example groups D and G to more accurately reflect the baseline for these examples. This will not, however, alter the path to compliance for SHQS and EESSH.
6	When considering retrofit example groups A to D, social landlords should consider whether their property is likely to have had a chimney and/or flue in 1990 (section 3.2.6). This will influence infiltration and heat load requirements which may vary from the modelled example. Again, this will not alter the path to compliance for SHQS and EESSH.

7	Assessors and social landlords should adopt the suggested minimum boiler efficiencies (section 3.2.7) when using RdSAP 2009 (v9.91) to assess properties.
8	Renewable energy technologies (such as PV and solar thermal) should be noted as „advanced" rather than „further" measures, due to the limiting factors associated with retrofitting (section 3.2.9). This mean considering the scope for alternative measures to achieve compliance with EESSH.
9	The inclusion of micro-CHP and micro-wind systems in the list of measures should be reviewed in relation to how applicable they are to most archetypes.
10	The Scottish Government should consider the scope for accepting documentary evidence from landlords in cases where properties are prevented from meeting the standard due to planning regulations relating to historic or otherwise protected buildings.
11	For system-built and high-rise properties, the EESSH should be designed to encourage the early adoption of EWI. For this reason EWI should be noted a „further" measure based on securing ECO funding where this is available to meet the cost of measures. 18 target property types are identified which would benefit from this approach.

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Appendix A – Housing Stock Summary

Building form	Construction Period	Current Scottish Stock[1] 000s (% of stock)	Example Dwelling Representation		Additional Hard-to-treat representation	
			No.	Reference (Group)	No.	References
Tenements	Pre 1919	166 (7.1 %)	3	A1: Solid wall, ground floor, mid terrace A2: Solid wall, mid-floor, mid terrace A3: Solid wall, top floor, mid terrace	2	HTT-HTT-1: Solid wall, gable end, ground floor HTT-2: Solid wall, gable end, top floor, partial flat roof
	1919 – 1944	45 (1.9 %)	1	B4: 1919-1929, cavity wall, mid-floor		
	1945 – 1964	107 (4.5 %)	1	D9: 1950-1964, cavity wall, mid-floor	2	HTT-7: No Fines Concrete, ground floor, gable end HTT-8: No Fines Concrete, top floor, gable end
	1965 – 1982	94 (4.0 %)	1	E12: 1965-1975, cavity wall, mid-floor		
	Post 1982	124 (5.3 %)	3	F15: 1984-1991 insulated		

[1] 'Scottish House Condition Survey – Key Findings 2010', The Scottish Government, November 2011

				wall, mid-floor G18: 1992-1998 insulated wall, mid-floor H21: 1999-2007 insulated wall, mid-floor		
Other Flats	Pre 1919	56 (2.4 %)				
	1919 – 1944	103 (4.4 %)	2	C7: Lower 4 in a block C8: Upper 4 in a block		
	1945 – 1964	79 (3.4 %)				
	1965 – 1982	46 (2.0 %)				
	Post 1982	43 (1.8 %)				
Terraced Houses	Pre 1919	67 (2.8 %)				
	1919 – 1944	37 (1.6 %)	1	B5: 1919-1929, cavity wall, mid-terrace		
	1945 – 1964	175 (7.4 %)	1	D10: 1950-1964, cavity wall, mid-terrace		
	1965 – 1982	163 (6.9 %)	1	E13: 1965-1975, cavity wall, mid-terrace		
	Post 1982	54 (2.3 %)	3	F16: 1984-1991. insulated wall G19: 1992-1998, insulated wall H22: 1999-2007, insulated wall		
Semi-detached houses	Pre 1919	62 (2.6 %)				
	1919 – 1944	73 (3.1 %)	1	B6: 1919-1929, cavity		

				wall		
	1945 – 1964	145 (6.2 %)	1	D11: 1950-1964, cavity wall	1	HTT-10: 1950's, Timber frame, semi-detached
	1965 – 1982	132 (5.6 %)	1	E14: 1965-1975, cavity wall		
	Post 1982	82 (3.5 %)	3	F17: 1984-1991, insulated wall G20: 1992-1998, insulated wall H23: 1999-2007 insulated wall		
Detached houses	Pre 1919	105 (4.5 %)				
	1919 – 1944	39 (1.7 %)				
	1945 – 1964	48 (2.0 %)				
	1965 – 1982	103 (4.4 %)				
	Post 1982	208 (8.8 %)				

HTT-3: 1950-64 system built concrete multi-storey flat ground floor, gable end
HTT-4: 1950-64system built concrete multi-storey flat mid-floor, gable end
HTT-5: 1950-64 external deck access, ground floor, gable end
HTT-6: 1950-64 external deck access, mid-floor gable end
HTT-9: Swedish timber house, semi-detached
HTT-11: System built concrete house, semi-detached
HTT-12: BISF steel frame house, semi-detached

Appendix B – Annex C of the SHQS

ANNEX C: MUST BE ENERGY EFFICIENT (5 ELEMENTS 2 SUB-ELEMENTS)

A	B	C	D	E
Element reference number	**Description of elements**	**Element type (internal to dwelling, common element or external to dwelling)**	**Interpretation for social landlords**	**Technical notes on measuring failure**
Effective insulation (3 elements)	**One or more** element failures under items 31-33 means outright failure of the energy efficiency criteria (C) and thus outright SHQS failure. Thus, elements 31, 32, 33 must be passedn **addition** to passing criteria 35 in order for SHQS to be met in full.			
31	Cavity wall insulation	External to dwelling or common element	This will include a need to test for the presence of cavity wall insulation that has been installed to the external wall since the property was built depending on the accuracy of records of which properties have had cavities filled. This is only required where the installation is technically feasible and appropriate.	1. In some types of dwellings (such as stone built properties and some forms of non-traditional build housing) it is not possible to install cavity wall insulation as no cavity is present. 2. In other cases, installation may be prohibited by building regulations because cavity wall insulation would lead to other problems such as water penetration and dampness. This is particularly true in the wettest areas and where properties are have the greatest exposure to the elements. 3. A property that is not capable of receiving cavity wall insulation for either reason does not fail SHQS on this criteria. 4. Further advice is available in a separate SG guidance note on SHQS technical feasibility, exemptions and abeyances which is published alongside this technical guidance.
32	At least 100mm **minimum** of existing loft insulation e.g. glass wool or equivalent (or 270mm for first time insulation or first time additional insulation or as a further measure to reduce carbon emissions)	Internal to dwelling or common element	100mm is the minimum existing level of loft insulation which will meet the SHQS. If the roof space is partially boarded without any loft insulation under the boards, or where the loft insulation is of uneven thickness, landlords need to ensure that the **average** thickness across the loft floor area is over 100mm.	1. In properties without a loft space it is not possible to install loft insulation so that property should not be regarded as failing on this element (see Annex I on exemptions and abeyances). 2. Though the SHQS minimum is 100mm of loft insulation, in order to minimise carbon emissions, Scottish Government would encourage up to 270mm of loft insulation as recommended under current Building Standards. We are aware that many landlords have gone beyond the 100mm depth in any case though would stress this is the official minimum necessary for passing SHQS. Up to 270mm is desirable however and can be fitted at a relatively small marginal cost.
33	Hot water tank and pipe insulation & cold water tank insulation as an ancillary measure	Internal dwelling	Hot water tanks (wherever they are located in the house) should have either spray-on insulation to a minimum thickness of 25mm or have an added tank jacket to a minimum thickness of 80mm. Where pipe work or cold water tanks are located in the loft space and are part of the distribution of heat within a wet heating system or delivery of hot or cold water to kitchens or bathrooms, these must be suitably insulated to protect against potential freezing conditions.	1. Alternatively, this requirement can be met if tanks and pipes are covered with a general insulation blanket or where they are completely located in a space with a rigid insulation system fixed to the underside of the roof (otherwise known as a 'warm roof'). Insulation is not required where exposed pipes will contribute to the heating requiremen of the room space in which it is situated.

Element reference number	Description of elements	Element type (internal to dwelling, common element or external to dwelling)	Interpretation for social landlords	Technical notes on measuring failure
Full, efficient central heating (1 element, 2 sub-elements)	**One or more** element failures under items 34A-34B means outright failure of the energy efficiency criteria (C) and thus outright SHQS failure. Thus, elements 34A-34B must be passedn **addition** to passing criteria 35 in order for SHQS to be met in full.			
34A	Full central heating	Internal dwelling	The definition of full house central heating is that all habitable rooms (i.e. excluding kitchen and bathroom which are not habitable rooms) covering at least 50% of the dwelling's floor area must have a heating system controlled from a single point in the dwelling.	1. Independently controlled heaters (i.e. not controlled from a single point), even if present in all rooms, do not constitute a central heating system and therefore would not meet the criteria. Thus, a number of independently controlled room heaters of various types do not constitute central heating and therefore do not pass criteria 34A even if a heating source is present in every habitable room. 2. Full electric central heating can consist of off-peak electric storage heaters and on-peak panel heaters which, together, cover all of the dwelling. The storage heaters should be controlled from a single point in the dwelling which is usually a timeclock or teleswitch controlled by the energy supplier. These will provide heating to the rooms they are located in plus 'drift' heat to those rooms not containing storage heaters. In addition, on-peak, independently controlled panel heaters can be used to supplement the heating to other rooms (with or without storage heating) where necessary. 3. The SHQS definition of habitable rooms is consistent with the definition of habitable rooms used in the Standard Assessment Procedure (SAP, element 35).
34B	Efficient central heating	Internal dwelling	1. An inefficient **full central heating system** is defined as being: a solid fuel boiler with an annual seasonal efficiency of 55% or less; a natural gas boiler with an annual seasonal efficiency of 55% or less; an oil-fired boiler with an annual seasonal efficiency of 65% or less; any gravity or semi-gravity heating system. 2. An inefficient **electric storage heating system** is defined here as being : free-standing large volume storage heaters; free standing compact storage heaters; electric fan-assisted storage warm air heating; electric wired under floor heating set in solid floors; electric ceiling heating. As a further guide to deciding on the efficiency or otherwise of such systems these storage heating systems, to be classed as inefficient, must also have been installed before 1984.	1. See footnote 2 at the bottom of this table. 2. The efficiency of individual central heating systems of differing fuel types can be validated in the Standard Assessment Procedure (SAP) handbook. The efficiency of individual boilers can be validated at http://www.sedbuk.com. 3. A 100% stock database is the most effective tool for identifying the detailed central heating characteristics of individual properties. There is no actual requirement for landlords to establish a 100% stock database though there was a recommendation that, over time, landlords should work towards a 100% stock database (as opposed to a 100% stock survey) by 2015 that would be capable of recording all relevant SHQS information (including central heating) for individual properties. 4. These efficiency ratings, specified in 2004, broadly equate to a 'G-rated' boiler or better suggesting that the requirements for an efficient central heating system under SHQS are not onerous. However, this definition of an efficient heating system was specified in 2004. To reduce fuel poverty and carbon emissions from the social housing stock, Scottish Government would strongly encourage landlords to aim for the most efficient boilers available on the market (i.e. A-rated) which will in practice mean going beyond the minimum specified in 2004.

Element reference number	Description of elements	Element type (internal to dwelling, common element or external to dwelling)	Interpretation for social landlords	Technical notes on measuring failure
A minimum energy efficiency rating (1 element)	All other elements of the energy criteria must be passed **in addition** to passing criteria 35 in order for SHQS to be met in full.			
35	An energy efficiency rating of **either** National Home Energy Rating (NHER) 5 **or** Standard Assessment Procedure (SAP) 2001 of 50 (gas systems) or 60 (electric systems).[4] See conversion table below to adjust SAP 2001 ratings to SAP 2005 or SAP 2009.	Internal dwelling	1. This criteria was referred to as 'additional energy efficiency measures' in the original (2004) guidance. However, we have changed the emphasis of this criteria (though not the criteria itself) to make it clearer and to reflect the fact that the property must meet a certain energy efficiency rating rather than exhibit actual the 'additional energy efficiency measures' themselves. 2. The measures that would enhance energy efficiency will be well-known to landlords but might include (a) going above the minimum to criteria for elements 31-33 e.g. more loft insulation or a highly efficient heating system or (b) introducing other separate heating/insulation measures additional to those outlined in criteria 31-33 such as low energy lighting, double or even triple glazing.	1. If a property has met all of criteria 31,32, 33, 34A and 34B and still fails to achieve a minimum NHER rating of 5 or a SAP 2001 rating of 50 (gas) and 60 (other fuel types) then the aforementioned 'additional energy efficiency' measures should be introduced subject to technical feasibility and proportionate costs. 2. There is no need to re-survey stock given the ongoing changes in the SAP system from SAP 2001 to SAP 2005 and again to SAP 2009 for example. Changes in the SAP scale do not change SHQS which is specified in SAP 2001. 3. A SAP 'conversion table' for SAP 2001, 2005 and 2009 is provided below. This table essentially shows the threshold for a 'pass' on criteria 35. This table may change periodically with ongoing changes to SAP.

1. The failure rates recorded here are substantially higher than expected. This may be because of the technical difficulties in checking for the presence of cavity wall insulation e.g. bore holes have been covered by external rendering, surveyors no longer checking for the presence of CWI by looking down into the cavity from the loft space. These technical difficulties are expected to be reduced or overcome by the time of the 2010 SHCS thus it is quite possible that the 2010 failure rate will be significantly lower than 2009 failure rate.

2. The initial Scottish Executive Guidance (February 2004 and July 2004) on electric storage systems failing if they are 'over 20 years' old should be disregarded. This was an oversight on the part of that Guidance. The correct failure criteria is that systems will fail element 34B if they were installed pre-1984 i.e. 20 years before the first draft of the SHQS was published.

3. The SAP requirements of SHQS (aimed at the social sector) are slightly different from those of the Scottish Government's Energy Assistance Package (which is aimed at all households). Details can be found here: http://www.energysavingtrust.org.uk/scotland/Scotland-Welcome-page/At-Home/Energy-Assistance-Package/Your-Questions-Answered/Energy-Ratings).

Conversion table showing minimum NHER/SAP 2001/2005/2009 ratings necessary to pass SHQS criteria 35

Fuel source for central heating systems	National Home Energy Rating) NHER	Standard Assessment Procedure (SAP) 2001	Standard Assessment Procedure (SAP) 2005/RdSAP	Standard Assessment Procedure (SAP) 2009
Gas	5	50	50	48
Oil	5	60	54	54
Liquid Petroleum Gas (LPG)	5	60	54	63
Electric	5	60	58	63
Solid Fuel	5	60	59	63
Biomass (new since 2004)	5	60	59	64

Appendix C

Developing an Energy Efficiency Standard for Social Housing
Proposed Ratings in the consultation document

Standard for gas heated homes for 2020

Broad Type	Minimum EPC (EI) Rating for the standard	Minimum EPC (EE) rating for the standard
Top floor flat heated by gas	C (70)	C (75)
Mid floor flats heated by gas	C (80)	C (80)
Ground floor flat heated by gas	D (65)	C (70)
Mid-terraced house heated by gas	C (70)	C (75)
End-terrace / Semi-detached house heated by gas	D (65)	C (70)
Four in a block – Lower heated by gas	D (60)	D (65)
Four in a block – Upper heated by gas	D (60)	D (65)
Detached / bungalow heated by gas	D (55)	D (60)

Standard for electrically heated homes for 2020

Broad Type	Minimum EPC (EI) Rating for the standard	Minimum EPC (EE) rating for the standard
Top floor flat heated by electricity	D (60)	D (65)
Mid floor flats heated by electricity	C (70)	C (70)
Ground floor flat heated by electricity	E (50)	D (60)
Mid-terraced house heated by electricity	D (55)	D (60)
End-terrace / Semi-detached house heated by electricity	E (50)	D (60)
Four in a block – Lower heated by electricity	E (50)	D (60)
Four in a block – Upper heated by electricity	D (55)	D (60)
Detached / bungalow heated by electricity	E (50)	D (55)

Appendix D – Pre- & Post-2002 Specs

Example Group H Performance Parameters

The period of construction describing example group H bridges two RdSAP age bands; I (1999-2002), and J (2003-2007). The reason for this split in the RdSAP age bands is due to changes in the buildings standards, most significantly the 6th amendment which came into force from 4th March 2002. This saw not only the application of more onerous U-values for external constructions, but a difference in the values relative to the fuel type and efficiency of the system. As a result, many of the default RdSAP assumptions demonstrate very different performance parameters.

The tables below summarise the performance parameters associated with the default RdSAP assumptions, example dwelling specifications, minimum Building Standards in place at the beginning of the example group H construction period, and the changes which came into force halfway through.

Walls – Table 1 summarises the wall U-values determined by the default RdSAP assumptions for a number of Scottish construction types, as well as the original and updated U-value criteria applicable to new constructions. The wall U-values are in compliance with the Building Standards corresponding to the earlier time period, relative to age band I. The latter half of the construction period, relative to RdSAP age band J, are subject to more onerous U-values.

Period	**U-value**
RdSAP	
Age Band I (1999-2002)	0.45 $W/m^2.K$* 0.40 $W/m^2.K$**
Age Band J (2003-2007)	0.30 $W/m^2.K$* 0.30 $W/m^2.K$**
4th amendment to the Technical Standards (1997) (in force from 29/12/97)	
SAP rating =< 60	0.45 $W/m^2.K$
SAP rating > 60	0.45 $W/m^2.K$
6th amendment to the Technical Standards (2001) (in force from 04/03/02)	
Gas boiler efficiency >=78%	0.30 $W/m^2.K$
Electric heating or gas boiler with efficiency <78%	0.27 $W/m^2.K$
* Based on 'cavity as built' or 'system build as built' ** Based on 'timber frame as built'	

Table 1 Example group H wall U-values

Floor – Table 2 summarises the floor U-values determined by the default RdSAP assumptions and calculation methodology. It can be seen that the floor U-values for example dwellings 22 and 23, are in compliance for the earlier period of the timeframe corresponding to age band I.

RdSAP	
Period	**U-value**
Age Band I (1999-2002) Solid ground floor, 50mm all-over floor insulation	Example dwelling 22: 0.26 $W/m^2.K$ Example dwelling 23: 0.33 $W/m^2.K$
Age Band J (2003-2007) Solid ground floor, 75mm all-over floor insulation	Example dwelling 22: 0.22 $W/m^2.K$ Example dwelling 23: 0.26 $W/m^2.K$
4th amendment to the Technical Standards (1997) (in force from 29/12/97)	
SAP rating =< 60	0.35 $W/m^2.K$
SAP rating > 60	0.45 $W/m^2.K$
6th amendment to the Technical Standards (2001) (in force from 04/03/02)	
Gas boiler efficiency >=78%	0.25 $W/m^2.K$
Electric heating of gas boiler with efficiency <78%	0.22 $W/m^2.K$

Table 2 Example group H floor U-values

Roof – Table 3 shows the U-values for the various criteria assuming a pitched roof with insulation between joists. The specification for the example dwelling roof insulation is 200mm. Based on this assumption, new dwellings completed between 1999 to the beginning of 2002 would meet compliance, however as of the 6th amendment to the Building Standards an increase in the loft insulation thickness would be necessary.

RdSAP	
Period	**U-value**
Age Band I (1999-2002) 150mm insulation	0.26 $W/m^2.K$
Age Band J (2003-2007) 250mm insulation	0.16 $W/m^2.K$
Specified thickness of 200mm insulation	0.20 $W/m^2.K$
4th amendment to the Technical Standards (1997) (in force from 29/12/97)	
SAP rating =< 60	0.20 $W/m^2.K$
SAP rating > 60	0.25 $W/m^2.K$
6th amendment to the Technical Standards (2001) (in force from 04/03/02)	

Gas boiler efficiency >=78%	0.16 $W/m^2.K$
Electric heating of gas boiler with efficiency <78%	0.16 $W/m^2.K$

Table 3 Example group H roof U-values

Windows – Table 4 details the RdSAP window U-value assumptions and the minimum building standards applicable to the construction period from 1999 to 2007. The specification for example group H baseline glazing is 'post-2003', however the RdSAP data for glazing installed before 2003 is also provided for reference.

It can be seen that specification of 'post-2003' standards ensures that the majority of the example dwellings meet compliance with the more recent buildings standards, however the properties featuring electric heating require an even lower U-value, of 1.8 $W/m^2.K$. It would be expected that properties constructed in the earlier half of the example group H timeframe, up to 2002, would have a poorer U-value than the assumed 2.0 $W/m^2.K$.

RdSAP	
Period	**U-value**
Double glazed unit, Scotland, before 2003	3.1 $W/m^2.K$
Double glazed unit, Scotland, 2003 or later	2.0 $W/m^2.K$
4th amendment to the Technical Standards (1997) (in force from 29/12/97)	
SAP rating =< 60	3.0 $W/m^2.K$
SAP rating > 60	3.3 $W/m^2.K$
6th amendment to the Technical Standards (2001) (in force from 04/03/02)	
Gas boiler efficiency >=78%	2.0 $W/m^2.K$
Electric heating of gas boiler with efficiency <78%	1.8 $W/m^2.K$

Table 4 Example group H window U-values

Appendix E – Loft Insulation Summary

All U-values detailed in the table below are based on a pitched (slate or tile) roof with insulation positioned between the joists. The proposed 1990 baseline assumptions detailed in column (vi) are consistent with the original 1990 baseline assumptions detailed in column (ii), subject to the following exceptions:

- An assumed loft insulation thickness of 12mm has been specified for example group D, corresponding to a U-value of 1.5 $W/m^2.K$. This is based on data detailed by the CE84 document for dwellings constructed between 1955 and 1975. Observations from the 2004/05 SHCS also noted that a quarter of the houses without loft insulation were constructed between 1945 and 1964, however this only represents 5% of the dwellings from this construction period[1].
- An increased loft insulation thickness of 150mm has been suggested for example group G, in line with the default RdSAP assumption relative to age band H and the data reported in the CE84 document. This corresponds to an improved U-value of 0.29 $W/m^2.K$, compared to the original 0.40 $W/m^2.K$.

[1] The Housing (Scotland) Act 2006: Guidance for local authorities Volume 4: The Tolerable Standard.

<table>
<tr><td>(i)</td><td colspan="2">(ii)</td><td colspan="3">(iii)</td><td>(iv)</td><td colspan="2">(v)</td><td colspan="2">(vi)</td></tr>
<tr><td rowspan="2">RdSAP age band</td><td rowspan="2" colspan="2">Example groups: 1990 Baseline ($W/m^2.K$)</td><td colspan="3">RdSAP Assumed Roof U-value</td><td colspan="3">CE84 Roof U-value[2]</td><td rowspan="2" colspan="2">Proposed Loft Insulation properties for example groups 1990 Baseline ($W/m^2.k$)</td></tr>
<tr><td>Relative to age band[3] ($W/m^2.K$)</td><td colspan="2">Relative to example group thickness[4] ($W/m^2.K$)</td><td>Relative to construction period[5] ($W/m^2.K$)</td><td colspan="2">Relative to example group specified thickness[6] ($W/m^2.K$)</td></tr>
<tr><td>A (Before 1900)</td><td colspan="2">A: No insulation</td><td rowspan="4">2.3 (none)</td><td colspan="2">2.3 (none)</td><td rowspan="3">(until 1954) 1.6* (none)</td><td colspan="2">2.3 (none)
1.6* (none)</td><td colspan="2">2.3 (none)</td></tr>
<tr><td>B (1919 - 1929)</td><td></td><td rowspan="2">C: No insulation</td><td></td><td rowspan="2">2.3 (none)</td><td></td><td rowspan="2">2.3 (none) 1.6* (none)</td><td></td><td rowspan="2">2.3 (none)</td></tr>
<tr><td>C (1930 - 1949)</td><td>B: No insulation</td><td>2.3 (none)</td><td>2.3 (none) 1.6* (none)</td><td>2.3 (none)</td></tr>
<tr><td>D (1950 - 1964)</td><td colspan="2">D: No insulation</td><td colspan="2">2.3 (none)</td><td rowspan="2">(1955 – 1975) 1.5 (12mm) 1.1* (12mm)</td><td colspan="2">2.3 (none)
1.6* (none)</td><td colspan="2">1.5 (12mm)</td></tr>
<tr><td>E (1965 - 1975)</td><td colspan="2"></td><td>1.5 (12mm)</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>F (1976 - 1983)</td><td colspan="2">E: 50mm</td><td>0.68 (50mm)</td><td colspan="2">0.68 (50mm)</td><td>0.68 (50mm)</td><td colspan="2">0.68 (50mm)
0.60* (50mm)</td><td colspan="2">0.68 (50mm)</td></tr>
</table>

[2] 'CE84 Scotland: Assessing U-values of existing housing, Energy Efficiency Best Practice in Housing', Energy Saving Trust, August 2004

[3] 'Table S10: Assumed roof U-value when Table S9 does not apply', RdSAP 2009 version 9.91

[4] ' Table S9: Roof U-values when loft insulation thickness at joists is known', RdSAP 2009 version 9.91

[5] 'Table 4: Default U-values for roofs by age, with known quantities of loft insulation thickness or unknown levels of roof insulation', CE84, August 2004

[6] 'Table 3: Default U-values when loft insulation thickness is known', CE84, August 2004

<table>
<tr><td>G (1984 - 1991)</td><td>F: 100mm</td><td>0.40 (100mm)</td><td>0.40 (100mm)</td><td>0.40 (100mm)</td><td>0.40 (100mm) 0.37* (100mm)</td><td>0.40 (100mm)</td></tr>
<tr><td>H (1992 - 1998)</td><td>G: 100mm</td><td>0.29 (150mm)</td><td>0.40 (100mm)</td><td>0.29 (150mm)</td><td>0.40 (100mm) 0.37* (100mm)</td><td>0.29 (150mm)</td></tr>
<tr><td>I (1999 - 2002)</td><td rowspan="2">H: 200mm</td><td>0.26 (150mm)</td><td rowspan="2">0.20 (200mm)</td><td>0.26 (150mm)</td><td rowspan="2">0.20 (200mm) 0.19* (200mm)</td><td rowspan="2">0.20 (200mm)</td></tr>
<tr><td>J (2003 - 2007)</td><td>0.16 (250mm)</td><td>0.16 (250mm)</td></tr>
</table>

* U-value calculated assuming unventilated sarking board, as featured in many older houses. The effect of ventilation, or specification of sarking felt, tends to raise the U-value slightly, contributing to increased heat loss

Annex F Software Remodelling Results for RdSAP versions

Table 1 Original Consultation Results Energy Efficiency Rating

Retrofit examples	Consultation draft (RdSAP 2005 v9.83) EE results							
	Baseline		SHQS		2020		2050	
	EE		EE		EE		EE	
A-1E	E	44	E	58			C	71
A-2E	D	56	D	67			C	78
A-3E	F	26	D	61	C	70	C	75
A-1G	D	58	D	62	C	76	B	82
A-2G	D	65	C	70	B	81	B	85
A-3G	E	43	D	67	B	81	B	84
B-4E	D	56	C	69	C	73	C	80
B-5E	F	23	D	62			C	70
B-6E	G	17	D	61			C	70
B-4G	D	66	C	73	B	86		
B-5G	E	41	D	64	C	79	B	86
B-6G	F	35	D	59	C	76	B	84
C-7E	F	34	D	62			D	68
C-8E	G	16	D	63	C	69	B	82
C-7G	E	46	D	59	C	75	C	80
C-8G	F	34	D	63	C	79	A	92
D-9E	D	63	C	72	C	80		
D-10E	F	26	D	61			C	76
D-11E	G	13	D	60			D	63
D-9G	D	68	C	76	B	84	B	86
D-10G	E	43	D	61	C	76	B	86
D-11G	F	32	E	53	C	72	B	82
E-12E	D	68	C	74	B	82		
E-13E	F	34	D	61	D	63	C	69
E-14E	F	32	D	60			C	71
E-12G	C	71	C	76	B	84		
E-13G	E	45	D	55	C	77	B	86
E-14G	E	47	D	55	C	74	B	86
F-15E	C	75			C	80	B	83
F-16E	E	51	D	59			C	72
F-17E	E	45	D	58	D	61	D	65
F-15G	C	75			B	87		
F-16G	D	62			C	80	B	85
F-17G	E	50			C	78	B	83
G-18E	C	73			C	78		
G-19E	D	55	D	64	C	70		
G-20E	E	50	D	59	D	66		
G-18G	C	77			B	85		
G-19G	D	66			C	80	B	86
G-20G	D	64			C	75	B	82
H-21E	C	78			B	82		

H-22E	D	68			C	73	C	79
H-23E	D	65			C	70	C	76
H-21G	D	63			B	87		
H-22G	D	65			C	70	C	75
H-23G	D	59			D	67	C	72

Table 2 SAP 9.90 Results Energy Efficiency Rating

Retrofit examples	Remodelled (RdSAP 2009 v9.90) EE results							
	Baseline		**SHQS**		**2020**		**2050**	
	EE		**EE**		**EE**		**EE**	
A-1E	E	52	D	65			C	74
A-2E	D	64	C	72			C	80
A-3E	F	35	D	67	C	74	C	79
A-1G	E	51	D	56	C	71	C	76
A-2G	D	59	D	63	C	75	C	80
A-3G	E	40	D	62	C	76	C	79
B-4E	D	68	C	79	B	81	B	83
B-5E	F	36	C	73			C	80
B-6E	F	27	C	69			C	76
B-4G	D	64	C	71	B	82		
B-5G	E	42	D	62	C	76	B	83
B-6G	F	36	D	59	C	74	B	81
C-7E	E	47	C	71			C	75
C-8E	F	25	C	70	C	74	B	85
C-7G	E	50	D	61	C	74	C	78
C-8G	F	34	D	61	C	76	B	89
D-9E	C	69	C	77	B	84		
D-10E	E	40	C	72			C	80
D-11E	F	22	C	71			C	73
D-9G	D	67	C	74	B	81	B	84
D-10G	E	44	D	60	C	74	B	82
D-11G	F	33	E	53	C	70	C	79
E-12E	C	72	C	78	B	84		
E-13E	E	44	D	66	D	68	C	77
E-14E	E	42	D	69			C	77
E-12G	D	66	C	71	B	82		
E-13G	E	47	D	56	C	75	B	81
E-14G	E	47	D	60	C	75	B	82
F-15E	C	79			B	82	B	85
F-16E	D	63	C	70			C	77
F-17E	E	51	D	67	C	69	C	71
F-15G	C	71			B	81		
F-16G	D	59			C	76	C	80
F-17G	E	52			C	72	C	76
G-18E	C	76			C	80		
G-19E	D	65	C	74	C	78		

G-20E	D	59	D	67	C	72		
G-18G	C	69			C	80		
G-19G	D	65			C	76	B	81
G-20G	D	61			C	73	C	78
H-21E	B	81			B	84		
H-22E	C	73			C	77	B	82
H-23E	C	70			C	74	C	79
H-21G	C	79			B	83		
H-22G	C	75			C	80	B	85
H-23G	C	73			C	77	B	82

Table 3: Difference between 2005 & 2009 Versions of RdSAP: Energy Efficiency Rating

Retrofit examples	Difference in EE between RdSAP versions (2005 & 2009)							
	Baseline		SHQS		2020		2050	
	EE		EE		EE		EE	
	Band	Score	Band	Score	Band	Score	Band	Score
A-1E	Same	8	E to D	7			Same	3
A-2E	Same	8	D to C	5			Same	2
A-3E	Same	9	Same	6	Same	4	Same	4
A-1G	D to E	-7	Same	-6	Same	-5	B to C	-6
A-2G	Same	-6	C to D	-7	B to C	-6	B to C	-5
A-3G	Same	-3	Same	-5	B to C	-5	B to C	-5
B-4E	Same	12	Same	10	C to B	8	C to B	3
B-5E	Same	13	D to C	11			Same	10
B-6E	G to F	10	D to C	8			Same	6
B-4G	Same	-2	Same	-2	Same	-4		
B-5G	Same	1	Same	-2	Same	-3	Same	-3
B-6G	Same	1	Same	0	Same	-2	Same	-3
C-7E	F to E	13	D to C	9			D to C	7
C-8E	G to F	9	D to C	7	Same	5	Same	3
C-7G	Same	4	Same	2	Same	-1	Same	-2
C-8G	Same	0	Same	-2	Same	-3	A to B	-3
D-9E	D to C	6	Same	5	C to B	4		
D-10E	F to E	14	D to C	11			Same	4

D-11E	G to F	9	D to C	11			D to C	10
D-9G	Same	-1	Same	-2	Same	-3	Same	-2
D-10G	Same	1	Same	-1	Same	-2	Same	-4
D-11G	Same	1	Same	0	Same	-2	B to C	-3
E-12E	D to C	4	Same	4	Same	2		
E-13E	F to E	10	Same	5	Same	5	Same	8
E-14E	F to E	10	Same	9			Same	6
E-12G	C to D	-5	Same	-5	Same	-2		
E-13G	Same	2	Same	1	Same	-2	Same	-5
E-14G	Same	0	Same	5	Same	1	Same	-4
F-15E	Same	4			C to B	2	Same	2
F-16E	E to D	12	D to C	11			Same	5
F-17E	Same	6	Same	9	D to C	8	D to C	6
F-15G	Same	-4			Same	-6		
F-16G	Same	-3			Same	-4	B to C	-5
F-17G	Same	2			Same	-6	B to C	-7
G-18E	Same	3			Same	2		
G-19E	Same	10	D to C	10	Same	8		
G-20E	E to D	9	Same	8	D to C	6		
G-18G	Same	-8			B to C	-5		
G-19G	Same	-1			Same	-4	B to B	-5
G-20G	Same	-3			Same	-2	B to C	-4
H-21E	C to B	3			Same	2		
H-22E	D to C	5			Same	4	C to B	3
H-23E	D to C	5			Same	4	Same	3
H-21G	D to C	16			Same	-4		
H-22G	D to C	10			Same	10	C to B	10
H-23G	D to C	14			D to C	10	C to B	10

Table 4: Original Consultation Results Energy Environmental Rating

Retrofit examples	Consultation draft (RdSAP v9.83) EI results							
	Baseline		SHQS		2020		2050	
	EI		EI		EI		EI	
A-1E	F	38	E	47			D	62
A-2E	E	48	E	58			C	72
A-3E	F	22	E	50	D	61	C	69
A-1G	E	21	D	55	C	73	C	80
A-2G	D	60	D	65	C	79	B	84
A-3G	F	38	D	62	C	79	B	83
B-4E	D	55	C	70	C	73	C	75
B-5E	F	23	D	59			D	66
B-6E	G	15	E	51			D	59
B-4G	D	61	C	68	B	85		
B-5G	F	36	D	57	C	76	B	83
B-6G	F	30	E	51	C	72	C	80
C-7E	F	30	E	52			D	59
C-8E	G	13	D	55	D	61	C	73
C-7G	E	41	E	52	C	72	C	78
C-8G	F	29	D	56	C	76	B	89
D-9E	D	57	D	67	C	76		
D-10E	F	25	D	57			D	67
D-11E	G	11	E	49			E	53
D-9G	D	65	C	72	B	83	B	86
D-10G	F	38	E	54	C	73	B	82
D-11G	F	28	E	45	D	67	C	78
E-12E	D	62	D	68	C	77		
E-13E	F	30	E	51	E	54	D	59
E-14E	F	29	E	51			D	62
E-12G	D	68	C	72	B	83		
E-13G	F	40	E	48	C	74	B	83
E-14G	E	41	E	49	C	71	B	83
F-15E	C	71			C	74	C	78
F-16E	E	50	D	55			D	63
F-17E	E	39	E	47	E	49	E	53
F-15G	C	73			B	86		
F-16G	D	56			C	77	B	82
F-17G	E	44			C	75	C	80
G-18E	C	69			C	73		
G-19E	E	53	D	61	D	66		
G-20E	E	44	E	50	D	55		
G-18G	C	76			B	84		
G-19G	D	61			C	77	B	83
G-20G	D	58			C	72	C	78
H-21E	C	75			C	78		
H-22E	D	63			D	66	C	71
H-23E	D	58			D	61	D	66

H-21G	C	73			B	86		
H-22G	C	72			C	77	B	82
H-23G	D	68			C	74	C	78

Table 5 SAP 9.90 Results Environmental Rating

Retrofit examples	Remodelled (RdSAP v9.90) EI results							
	Baseline		SHQS		2020		2050	
	EI		EI		EI		EI	
A-1E	F	33	E	42			D	57
A-2E	E	43	E	53			C	69
A-3E	G	18	E	46	D	57	D	66
A-1G	E	49	E	53	C	72	C	79
A-2G	D	57	D	62	C	78	B	83
A-3G	F	38	D	59	C	78	B	82
B-4E	E	50	D	68	C	71	C	74
B-5E	G	19	D	55			D	63
B-6E	G	11	E	47			D	55
B-4G	D	63	C	70	B	86		
B-5G	E	39	D	59	C	76	B	84
B-6G	F	33	E	54	C	74	B	81
C-7E	F	28	E	51			D	57
C-8E	G	9	E	52	D	56	D	66
C-7G	E	46	D	56	C	74	C	79
C-8G	F	32	D	57	C	77	B	89
D-9E	E	52	D	64	C	75		
D-10E	F	22	E	54			D	64
D-11E	G	7	E	45			E	51
D-9G	D	65	C	73	B	83	B	86
D-10G	E	41	D	56	C	75	B	84
D-11G	F	30	E	48	C	69	C	79
E-12E	D	58	D	65	C	77		
E-13E	F	25	E	45	E	47	D	58
E-14E	F	24	E	49			D	57
E-12G	D	66	C	71	B	86		
E-13G	E	43	E	51	C	76	B	82
E-14G	E	42	D	55	C	74	B	82
F-15E	C	69			C	72	C	70
F-16E	E	44	E	49			D	57
F-17E	F	32	E	42	E	45	E	48
F-15G	C	73			B	86		
F-16G	D	55			C	77	B	81
F-17G	E	48			C	72	C	76
G-18E	D	64			C	69		
G-19E	E	47	E	54	D	60		
G-20E	E	39	E	45	E	50		

G-18G	C	69			B	83		
G-19G	D	64			C	77	B	83
G-20G	D	58			C	73	C	79
H-21E	C	74			C	77		
H-22E	D	57			D	60	D	65
H-23E	E	53			D	56	D	60
H-21G	B	84			B	87		
H-22G	C	76			B	81	B	86
H-23G	C	74			C	79	B	84

Table 6: Difference between 2005 & 2009 Versions of RdSAP: Environmental Rating

Retrofit examples	Difference in EI between RdSAP versions (2009 - 2005)							
	Baseline		SHQS		2020		2050	
	EI		EI		EI		EI	
	Band	Score	Band	Score	Band	Score	Band	Score
A-1E	Same	-5	Same	-5			Same	-5
A-2E	Same	-5	Same	-5			Same	-3
A-3E	F to G	-4	Same	-4	Same	-4	C to D	-3
A-1G	Same	28	D to E	-2	Same	-1	Same	-1
A-2G	Same	-3	Same	-3	Same	-1	Same	-1
A-3G	Same	0	Same	-3	Same	-1	Same	-1
B-4E	D to E	-5	C to D	-2	Same	-2	Same	-1
B-5E	F to G	-4	Same	-4			Same	-3
B-6E	Same	-4	Same	-4			Same	-4
B-4G	Same	2	Same	2	Same	1		
B-5G	F to E	3	Same	2	Same	0	Same	1
B-6G	Same	3	Same	3	Same	2	C to B	1
C-7E	Same	-2	Same	-1			Same	-2
C-8E	Same	-4	D to E	-3	Same	-5	C to D	-7
C-7G	Same	5	E to D	4	Same	2	Same	1
C-8G	Same	3	Same	1	Same	1	Same	0
D-9E	D to E	-5	Same	-3	Same	-1		
D-10E	Same	-3	D to E	-3			Same	-3
D-11E	Same	-4	Same	-4			Same	-2
D-9G	Same	0	Same	1	Same	0	Same	0
D-10G	F to E	3	E to D	2	Same	2	Same	2

D-11G	Same	2	Same	3	D to C	2	Same	1
E-12E	Same	-4	Same	-3	Same	0		
E-13E	Same	-5	Same	-6	Same	-7	Same	-1
E-14E	Same	-5	Same	-2			Same	-5
E-12G	Same	-2	Same	-1	Same	3		
E-13G	F to E	3	Same	3	Same	2	Same	-1
E-14G	Same	1	E to D	6	Same	3	Same	-1
F-15E	Same	-2			Same	-2	Same	-8
F-16E	Same	-6	D to E	-6			Same	-6
F-17E	E to F	-7	Same	-5	Same	-4	Same	-5
F-15G	Same	0			Same	0		
F-16G	Same	-1			Same	0	Same	-1
F-17G	Same	4			Same	-3	Same	-4
G-18E	C to D	-5			Same	-4		
G-19E	Same	-6	D to E	-7	Same	-6		
G-20E	Same	-5	Same	-5	D to E	-5		
G-18G	Same	-7			Same	-1		
G-19G	Same	3			Same	0	Same	0
G-20G	Same	0			Same	1	Same	1
H-21E	Same	-1			Same	-1		
H-22E	Same	-6			Same	-6	C to D	-6
H-23E	D to E	-5			Same	-5	Same	-6
H-21G	C to B	11			Same	1		
H-22G	Same	4			C to B	4	Same	4
H-23G	D to C	6			Same	5	C to B	6

Annex G Remodelled Case Study Results Summary

Building Type Group A Pre 1919 Solid Wall flats and houses

Case study A-1E: Pre 1919 solid wall dwelling - ground floor (55m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £831				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,765**	-	**£11,465**
Annual fuel cost savings	-	£213	-	£382
Percentage annual fuel cost savings	-	26%	-	46%
SAP Rating	E (52)	D (65)	-	C (74)
EI Rating	F (33)	E (42)	-	D (57)
Approximate CO_2 emissions kg/m^2/year	105	83	-	58
Percentage CO_2 improvement	-	21%	-	45%

Case study A-2E: Pre 1919 solid wall dwelling - mid floor (58m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £678				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,765**	-	**£13,965**
Annual fuel cost savings	-	£174	-	£324
Percentage annual fuel cost savings	-	26%	-	48%
SAP Rating	D (64)	C (72)	-	C (80)
EI Rating	E (43)	E (53)	-	C (69)
Approximate CO_2 emissions kg/m^2/year	79	62	-	41
Percentage CO_2 improvement	-	22%	-	48%

Case study A-3E: Pre 1919 solid wall dwelling - top floor (67m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,309				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	No insulation	-	Internal insulation **(£5,500)**
Floor	-	No insulation	-	-
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	Electric room heater	-	-
Ventilation	natural	natural	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£1,565**	**£5,548**	**£11,048**
Annual fuel cost savings	-	£664	-	£890
Percentage annual fuel cost savings	-	51%	-	68%
SAP Rating	F (35)	D (67)	C (74)	C (79)
EI Rating	G (18)	E (46)	D (57)	D (66)
Approximate CO_2 emissions kg/m^2/year	139	70	54	43
Percentage CO_2 improvement	-	50%	61%	69%

Case study A-1G: Pre 1919 solid wall dwelling - ground floor (55m²)				
Fuel type: Gas				
Baseline annual fuel costs: £823				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£3,715**	**£6,515**	**£16,915**
Annual fuel cost savings	-	£74	£333	£417
Percentage annual fuel cost savings	-	9%	40%	51%
SAP Rating	E (51)	D (56)	C (71)	C (76)
EI Rating	E (49)	E (53)	C (72)	C (79)
Approximate CO_2 emissions $kg/m^2/year$	71	65	37	28
Percentage CO_2 improvement	-	8%	48%	61%

Case study A-2G: Pre 1919 solid wall dwelling - mid floor (58m²)				
Fuel type: Gas				
Baseline annual fuel costs: £719				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£3,715**	**£6,515**	**£15,715**
Annual fuel cost savings	-	£77	£284	£364
Percentage annual fuel cost savings	-	11%	39%	51%
SAP Rating	D (59)	D (63)	C (75)	C (80)
EI Rating	D (57)	D (62)	C (78)	B (83)
Approximate CO_2 emissions kg/m²/year	57	52	30	22
Percentage CO_2 improvement	-	9%	47%	61%

Case study A-3G: Pre 1919 solid wall dwelling - top floor ($67m^2$)				
Fuel type: Gas				
Baseline annual fuel costs: £1,131				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	-	-	-	-
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,215**	**£7,298**	**£16,498**
Annual fuel cost savings	-	£408	£673	£736
Percentage annual fuel cost savings	-	36%	60%	65%
SAP Rating	E (40)	D (62)	C (76)	C (79)
EI Rating	F (38)	D (59)	C (78)	B (82)
Approximate CO_2 emissions $kg/m^2/year$	85	51	28	22
Percentage CO_2 improvement	-	40%	67%	74%

Building Type Group B – Interwar (1919-1949) Cavity Wall Houses and Flats

Case study B-4E: 1930-49 mid floor flat (78m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £698				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Manual charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 25mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,215**	**£5,265**	**£8,965**
Annual fuel cost savings	-	£248	£296	£333
Percentage annual fuel cost savings	-	36%	42%	48%
SAP Rating	D (68)	C (79)	B (81)	B (83)
EI Rating	E (50)	D (68)	C (71)	C (74)
Approximate CO_2 emissions kg/m^2/year	59	38	34	31
Percentage CO_2 improvement	-	36%	42%	47%

Case study B-5E: 1930-49 mid terrace (80m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,417				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,765**	-	**£14,965**
Annual fuel cost savings	-	£833	-	£866
Percentage annual fuel cost savings	-	59%	-	61%
SAP Rating	F (36)	C (73)	-	C (80)
EI Rating	G (19)	D (55)	-	D (63)
Approximate CO_2 emissions kg/m²/year	126	52	-	43
Percentage CO_2 improvement	-	59%	-	66%

Case study B-6E: 1930-49 semi-detached (92m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,848				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,768**	-	**£14,968**
Annual fuel cost savings	-	£1,105	-	£1,153
Percentage annual fuel cost savings	-	60%	-	62%
SAP Rating	F (27)	C (69)	-	C (76)
EI Rating	G (11)	E (47)	-	D (55)
Approximate CO_2 emissions kg/m^2/year	146	60	-	50
Percentage CO_2 improvement	-	59%	-	66%

Case study B-4G: 1930-49 mid floor flat (78m2)				
Fuel type: Gas				
Baseline annual fuel costs: £744				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	-	100% double glazing (post 2003) **(£3,700)**	
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£515**	**£7,015**	-
Annual fuel cost savings	-	£135	£377	-
Percentage annual fuel cost savings	-	18%	51%	-
SAP Rating	D (64)	C (71)	B (82)	-
EI Rating	D (63)	C (70)	B (86)	-
Approximate CO_2 emissions $kg/m^2/year$	44	35	17	-
Percentage CO_2 improvement	-	20%	61%	-

Case study B-5G: 1930-49 mid terrace (80m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,228				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£4,715**	**£7,798**	**£20,698**
Annual fuel cost savings	-	£428	£717	£758
Percentage annual fuel cost savings	-	35%	58%	62%
SAP Rating	E (42)	D (62)	C (76)	B (83)
EI Rating	E (39)	D (59)	C (76)	B (84)
Approximate CO_2 emissions kg/m^2/year	78	48	27	19
Percentage CO_2 improvement	-	38%	65%	76%

Case study B-6G: 1930-49 semi-detached (92m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,512				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£4,718**	**£7,801**	**£20,701**
Annual fuel cost savings	-	£559	£907	£956
Percentage annual fuel cost savings	-	37%	60%	63%
SAP Rating	F (36)	D (59)	C (74)	B (81)
EI Rating	F (33)	E (54)	C (74)	B (81)
Approximate CO_2 emissions kg/m^2/year	86	51	29	21
Percentage CO_2 improvement	-	41%	66%	76%

Building Type Group C - Four in a Block – 1920-1949

Case study C-7E: 1930-49 Four-in-a-block lower (94m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,282				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£5,268**	-	**£6,468**
Annual fuel cost savings	-	£585	-	£665
Percentage annual fuel cost savings	-	46%	-	52%
SAP Rating	E (47)	C (71)	-	C (75)
EI Rating	F (28)	E (51)	-	D (57)
Approximate CO_2 emissions kg/m²/year	97	55	-	48
Percentage CO_2 improvement	-	43%	-	51%

Case study C-8E: 1930-49 Four-in-a-block upper (87m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,843				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	-
Roof	No insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Manual charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 25mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£4,718**	**£5,768**	**£13,768**
Annual fuel cost savings	-	£1,159	£1,252	£1,252
Percentage annual fuel cost savings	-	63%	68%	68%
SAP Rating	F (25)	C (70)	C (74)	B (85)
EI Rating	G (9)	E (52)	D (56)	D (66)
Approximate CO_2 emissions kg/m^2/year	154	55	49	39
Percentage CO_2 improvement	-	64%	68%	75%

Case study C-7G: 1930-49 Four-in-a-block lower (94m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,169				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	-	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£518**	**£3,318**	**£8,218**
Annual fuel cost savings	-	£244	£559	£653
Percentage annual fuel cost savings	-	21%	48%	56%
SAP Rating	E (50)	D (61)	C (74)	C (78)
EI Rating	E (46)	D (56)	C (74)	C (79)
Approximate CO_2 emissions kg/m^2/year	62	48	29	23
Percentage CO_2 improvement	-	23%	53%	63%

Case study C-8G: 1930-49 Four-in-a-block upper (87m²)				
Fuel type: Gas				
Baseline annual fuel costs: £1,500				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	-
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£1,018**	**£4,101**	**£15,801**
Annual fuel cost savings	-	£635	£967	£1,020
Percentage annual fuel cost savings	-	42%	64%	68%
SAP Rating	F (34)	D (61)	C (76)	B (89)
EI Rating	F (32)	D (57)	C (77)	B (89)
Approximate CO_2 emissions kg/m²/year	90	48	26	12
Percentage CO_2 improvement	-	47%	71%	87%

Building Type Group D - 1950-1964 Cavity Wall Houses and Flats

Case study D-9E: 1950-1964 post war mid-floor flat (110m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £831				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Manual charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 25mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£518**	**£5,268**	-
Annual fuel cost savings	-	£218	£402	-
Percentage annual fuel cost savings	-	26%	48%	-
SAP Rating	C (69)	C (77)	B (84)	-
EI Rating	E (52)	D (64)	C (75)	-
Approximate CO_2 emissions kg/m^2/year	51	38	26	-
Percentage CO_2 improvement	-	25%	49%	-

Case study D-10E: 1950-1964 post war mid-terrace (70m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,220				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,765**	-	**£18,665**
Annual fuel cost savings	-	£665	-	£731
Percentage annual fuel cost savings	-	55%	-	60%
SAP Rating	E (40)	C (72)	-	C (80)
EI Rating	F (22)	E (54)	-	D (64)
Approximate CO_2 emissions kg/m^2/year	124	57	-	44
Percentage CO_2 improvement	-	54%	-	65%

Case study D-11E: 1950-1964 post war semi-detached (84m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,923				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	20% of roof area **(£8,000)**	-	-
Total cost of all measures applied since baseline	-	**£13,765**	-	**£14,965**
Annual fuel cost savings	-	£1,155	-	£1,208
Percentage annual fuel cost savings	-	60%	-	63%
SAP Rating	F (22)	C (71)	-	C (73)
EI Rating	G (7)	E (45)	-	E (51)
Approximate CO_2 emissions kg/m²/year	166	62	-	57
Percentage CO_2 improvement	-	63%	-	66%

Case study D-9G: 1950-1964 post war mid-floor flat (110m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £859				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	-	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£518**	**£3,318**	**£7,018**
Annual fuel cost savings	-	£176	£370	£439
Percentage annual fuel cost savings	-	20%	43%	51%
SAP Rating	D (67)	C (74)	B (81)	B (84)
EI Rating	D (65)	C (73)	B (83)	B (86)
Approximate CO_2 emissions kg/m^2/year	37	28	18	15
Percentage CO_2 improvement	-	24%	51%	59%

Case study D-10G: 1950-1964 post war mid-terrace (70m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,081				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	-	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£1,015**	**£4,098**	**£16,998**
Annual fuel cost savings	-	£299	£571	£645
Percentage annual fuel cost savings	-	28%	53%	60%
SAP Rating	E (44)	D (60)	C (74)	B (82)
EI Rating	E (41)	D (56)	C (75)	B (84)
Approximate CO_2 emissions kg/m^2/year	77	53	31	19
Percentage CO_2 improvement	-	31%	60%	75%

Case study D-11G: post war semi-detached (84m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,512				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	-	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£1,015**	**£4,098**	**£16,998**
Annual fuel cost savings	-	£488	£863	£952
Percentage annual fuel cost savings	-	32%	57%	63%
SAP Rating	F (33)	E (53)	C (70)	C (79)
EI Rating	F (30)	E (48)	C (69)	C (79)
Approximate CO_2 emissions kg/m^2/year	94	61	35	24
Percentage CO_2 improvement	-	35%	63%	74%

Building Type Group E – 1976-1983 flats and houses

Case study E-12E: 1976-83 mid-floor flat (60m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £510				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Manual charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 25mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£515**	**£5,265**	-
Annual fuel cost savings	-	£98	£221	-
Percentage annual fuel cost savings	-	19%	43%	-
SAP Rating	C (72)	C (78)	B (84)	-
EI Rating	D (58)	D (65)	C (77)	-
Approximate CO_2 emissions $kg/m^2/year$	55	45	31	-
Percentage CO_2 improvement	-	18%	44%	-

Case study E-13E: 1976-83 mid-terrace ($84m^2$)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,258				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	50mm insulation	100mm at joists **(£283)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	-	-	Electric immersion with 80mm factory applied foam **(£23)**
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,551**	**£5,834**	**£18,757**
Annual fuel cost savings	-	£497	£529	£634
Percentage annual fuel cost savings	-	40%	42%	50%
SAP Rating	E (44)	D (66)	D (68)	C (77)
EI Rating	F (25)	E (45)	E (47)	D (58)
Approximate CO_2 emissions $kg/m^2/year$	105	66	63	48
Percentage CO_2 improvement	-	37%	40%	54%

Case study E-14E: 1976-83 semi-detached (108m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,538				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	50mm insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,768**	-	**£14,968**
Annual fuel cost savings	-	£723	-	£777
Percentage annual fuel cost savings	-	47%	-	51%
SAP Rating	E (42)	C (69)	-	C (77)
EI Rating	F (24)	E (49)	-	D (57)
Approximate CO_2 emissions $kg/m^2/year$	101	55	-	46
Percentage CO_2 improvement	-	46%	-	54%

Case study E-12G: 1976-83 mid-floor flat (60m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £581				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£515**	**£7,015**	-
Annual fuel cost savings	-	£59	£260	-
Percentage annual fuel cost savings	-	10%	45%	-
SAP Rating	D (66)	C (71)	B (82)	-
EI Rating	D (66)	C (71)	B (86)	-
Approximate CO_2 emissions kg/m^2/year	44	37	18	-
Percentage CO_2 improvement	-	16%	59%	-

Case study E-13G: 1976-83 mid-terrace (84m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,151				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	Insulation **(£1,200)**
Roof	50mm insulation	100mm at joists **(£283)**	250mm at joists **(£283)**	-
Windows	100% single glazing	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£801**	**£7,584**	**£16,784**
Annual fuel cost savings	-	£190	£614	£638
Percentage annual fuel cost savings	-	17%	53%	55%
SAP Rating	E (47)	D (56)	C (75)	B (81)
EI Rating	E (43)	E (51)	C (76)	B (82)
Approximate CO_2 emissions kg/m^2/year	69	57	27	20
Percentage CO_2 improvement	-	17%	61%	71%

Case study E-14G: 1976-83 semi-detached (108m²)				
Fuel type: Gas				
Baseline annual fuel costs: £1,365				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	Cavity filled **(£500)**	-	-
Floor	-	-	-	Insulation **(£1,200)**
Roof	50mm insulation	100mm at joists **(£283)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£801**	**£3,884**	**£16,784**
Annual fuel cost savings	-	£334	£719	£772
Percentage annual fuel cost savings	-	24%	53%	57%
SAP Rating	E (47)	D (60)	C (75)	B (82)
EI Rating	E (42)	D (55)	C (74)	B (82)
Approximate CO_2 emissions $kg/m^2/year$	65	48	27	19
Percentage CO_2 improvement	-	26%	58%	71%

Building Type Group F – 1984-1991 houses and flats

Case study F-15E: 1984-91 mid-floor flat (60m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £392				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation	-	-	Additional wall insulation **(£5,550)**
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% double glazing (pre 2003)	-	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Modern slimline storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Automatic charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 25mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	-	**£1,065**	**£10,265**
Annual fuel cost savings	-	-	£59	£109
Percentage annual fuel cost savings	-	-	15%	28%
SAP Rating	C (79)	-	B (82)	B (85)
EI Rating	C (69)	-	C (72)	C (70)
Approximate CO_2 emissions $kg/m^2/year$	40	-	36	30
Percentage CO_2 improvement	-	-	10%	25%

Case study F-16E: 1984-91 mid-terrace (76m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £780				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	No insulation	-	-	-
Roof	100mm insulation	250mm at joists **(£283)**	-	-
Windows	100% double glazing (pre 2003)	-	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Modern slimline storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Automatic charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	-	-	Electric immersion with 80mm factory applied foam **(£23)**
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£1,348**	-	**£13,048**
Annual fuel cost savings	-	£138	-	£181
Percentage annual fuel cost savings	-	18%	-	23%
SAP Rating	D (63)	C (70)	-	C (77)
EI Rating	E (44)	E (49)	-	D (57)
Approximate CO_2 emissions kg/m^2/year	69	61	-	51
Percentage CO_2 improvement	-	12%	-	26%

Case study F-17E: 1984-91 semi-detached (74m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,010				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	No insulation	-	-	-
Roof	100mm insulation	250mm at joists **(£283)**	-	-
Windows	100% double glazing (pre 2003)	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Modern slimline storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Automatic charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	20% of roof area **(£8,000)**	-	-
Solar Hot Water				3m^2 **(£4,000)**
Total cost of all measures applied since baseline	-	**£9,348**	**£13,048**	**£17,048**
Annual fuel cost savings	-	£225	£264	£307
Percentage annual fuel cost savings	-	22%	26%	30%
SAP Rating	E (51)	D (67)	C (69)	C (71)
EI Rating	F (32)	E (42)	E (45)	E (48)
Approximate CO_2 emissions kg/m^2/year	95	74	69	64
Percentage CO_2 improvement	-	22%	27%	33%

Case study F-15G: 1984-91 mid-floor flat (60m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £517				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% double glazing (pre 2003)	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	-	**£6,515**	-
Annual fuel cost savings	-	-	£184	-
Percentage annual fuel cost savings	-	-	36%	-
SAP Rating	C (71)	-	B (81)	-
EI Rating	C (73)	-	B (86)	-
Approximate CO_2 emissions kg/m^2/year	36	-	19	-
Percentage CO_2 improvement	-	-	47%	-

Case study F-16G: 1984-91 mid-terrace (76m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £845				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	No insulation	-	-	-
Roof	100mm insulation	-	250mm at joists **(£283)**	-
Windows	100% double glazing (pre 2003)	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	-	**£6,798**	**£14,798**
Annual fuel cost savings	-	-	£348	£348
Percentage annual fuel cost savings	-	-	41%	41%
SAP Rating	D (59)	-	C (76)	C (80)
EI Rating	D (55)	-	C (77)	B (81)
Approximate CO_2 emissions kg/m^2/year	53	-	27	22
Percentage CO_2 improvement	-	-	49%	58%

Case study F-17G: 1984-91 semi-detached (74m²)				
Fuel type: Gas				
Baseline annual fuel costs: £969				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	No insulation	-	-	-
Roof	100mm insulation	-	250mm at joists **(£283)**	-
Windows	100% double glazing (pre 2003)	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	-	**£6,798**	**£14,798**
Annual fuel cost savings	-	-	£400	£400
Percentage annual fuel cost savings	-	-	41%	41%
SAP Rating	E (52)	-	C (72)	C (76)
EI Rating	E (48)	-	C (72)	C (76)
Approximate CO_2 emissions kg/m²/year	64	-	34	28
Percentage CO_2 improvement	-	-	47%	56%

Building Type Group G – 1992-1998 Houses and Flats

Case study G-18E: 1992-98 mid-floor flat (70m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £494				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation	-	-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% double glazing (pre 2003)	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Modern slimline storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Automatic charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 50mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	-	**£4,765**	-
Annual fuel cost savings	-	-	£93	-
Percentage annual fuel cost savings	-	-	19%	-
SAP Rating	C (76)	-	C (80)	-
EI Rating	D (64)	-	C (69)	-
Approximate CO_2 emissions kg/m^2/year	44	-	39	-
Percentage CO_2 improvement	-	-	11%	-

Case study G-19E: 1992-98 mid-terrace (76m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £732				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation	-	-	-
Floor	Insulation	-	-	-
Roof	100mm insulation	250mm at joists **(£283)**	-	-
Windows	100% double glazing (pre 2003)	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Modern slimline storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Automatic charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 25mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	20% of roof area **(£8,000)**	-	-
Total cost of all measures applied since baseline	-	**£8,298**	**£13,048**	-
Annual fuel cost savings	-	£71	£172	-
Percentage annual fuel cost savings	-	10%	23%	-
SAP Rating	D (65)	C (74)	C (78)	-
EI Rating	E (47)	E (54)	D (60)	-
Approximate CO_2 emissions kg/m²/year	64	55	47	-
Percentage CO_2 improvement	-	14%	27%	-

Case study G-20E: 1992-98 semi-detached ($74m^2$)				
Fuel type: Electricity				
Baseline annual fuel costs: £857				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation	-	-	-
Floor	Insulation	-	-	-
Roof	100mm insulation	250mm at joists **(£283)**	-	-
Windows	100% double glazing (pre 2003)	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Modern slimline storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Automatic charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 25mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	20% of roof area **(£8,000)**	-	-
Total cost of all measures applied since baseline	-	**£8,298**	**£13,048**	-
Annual fuel cost savings	-	£68	£184	-
Percentage annual fuel cost savings	-	8%	21%	-
SAP Rating	D (59)	D (67)	C (72)	-
EI Rating	E (39)	E (45)	E (50)	-
Approximate CO_2 emissions $kg/m^2/year$	79	69	61	-
Percentage CO_2 improvement	-	13%	23%	-

Case study G-18G: 1992-98 mid-floor flat (70m²)				
Fuel type: Gas				
Baseline annual fuel costs: £606				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% double glazing (pre 2003)	-	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 38mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	-	**£6,515**	-
Annual fuel cost savings	-	-	£219	-
Percentage annual fuel cost savings	-	-	36%	-
SAP Rating	C (69)	-	C (80)	-
EI Rating	C (69)	-	B (83)	-
Approximate CO_2 emissions kg/m²/year	38	-	21	-
Percentage CO_2 improvement	-	-	45%	-

Case study G-19G: 1992-98 mid-terrace (76m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £708				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	Insulation	-	-	-
Roof	100mm insulation	-	250mm at joists **(£283)**	-
Windows	100% double glazing (pre 2003)	-	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer, room thermostat and TRVs	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 38mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	-	**£3,098**	**£14,798**
Annual fuel cost savings	-	-	£210	£230
Percentage annual fuel cost savings	-	-	30%	32%
SAP Rating	D (65)	-	C (76)	B (81)
EI Rating	D (64)	-	C (77)	B (83)
Approximate CO_2 emissions kg/m^2/year	42	-	27	21
Percentage CO_2 improvement	-	-	36%	50%

Case study G-20G: 1992-98 semi-detached (74m²)				
Fuel type: Gas				
Baseline annual fuel costs: £792				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	Insulation	-	-	-
Roof	100mm insulation	-	250mm at joists **(£283)**	-
Windows	100% double glazing (pre 2003)	-	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer, room thermostat and TRVs	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 38mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	-	**£3,098**	**£14,798**
Annual fuel cost savings	-	-	£239	£257
Percentage annual fuel cost savings	-	-	30%	32%
SAP Rating	D (61)	-	C (73)	C (78)
EI Rating	D (58)	-	C (73)	C (79)
Approximate CO_2 emissions kg/m²/year	50	-	32	26
Percentage CO_2 improvement	-	-	36%	48%

Building Type Group H - 1999 to 2007 Houses and Flats

Case study H-21E: 1999-2007 mid floor flat (63m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £353				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation	-	-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% double glazing (post 2003)	-		-
Open chimneys	None	-	-	-
Heating system	Modern slimline storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Automatic charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 38mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	-	**£1,065**	-
Annual fuel cost savings	-	-	£57	-
Percentage annual fuel cost savings	-	-	16%	-
SAP Rating	B (81)	-	B (84)	-
EI Rating	C (74)	-	C (77)	-
Approximate CO_2 emissions kg/m^2/year	33	-	30	-
Percentage CO_2 improvement	-	-	9%	-

Case study H-22E: 1999-2007 mid-terrace (97m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £682				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation	-	-	-
Floor	Insulation	-	-	-
Roof	200mm insulation (assumed)	-	250mm at joists **(£283)**	-
Windows	100% double glazing (post 2003)	-		-
Open chimneys	None	-	-	-
Heating system	Modern slimline storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Automatic charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 38mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£18)**	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	-	**£1,351**	**£9,351**
Annual fuel cost savings	-	-	£100	£100
Percentage annual fuel cost savings	-	-	15%	15%
SAP Rating	C (73)	-	C (77)	B (82)
EI Rating	D (57)	-	D (60)	D (65)
Approximate CO_2 emissions kg/m^2/year	47	-	43	38
Percentage CO_2 improvement	-	-	9%	19%

Case study H-23E: 1999-2007 semi-detached (73m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £623				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation	-	-	-
Floor	Insulation	-	-	-
Roof	200mm insulation (assumed)	-	250mm at joists **(£283)**	-
Windows	100% double glazing (post 2003)	-		-
Open chimneys	None	-	-	-
Heating system	Modern slimline storage heaters	-	Fan storage heaters **(£1,050)**	-
Heating system controls	Automatic charge control	-	Automatic charge control **(included in storage heating costs)**	-
Hot water system	Electric immersion with 38mm factory applied foam	-	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£18)**	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	-	**£1,351**	**£9,351**
Annual fuel cost savings	-	-	£89	£89
Percentage annual fuel cost savings	-	-	14%	14%
SAP Rating	C (70)	-	C (74)	C (79)
EI Rating	E (53)	-	D (56)	D (60)
Approximate CO_2 emissions kg/m²/year	58	-	54	48
Percentage CO_2 improvement	-	-	7%	17%

Case study H-21G: 1999-2007 mid floor flat (63m²)				
Fuel type: Gas				
Baseline annual fuel costs: £377				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% double glazing (post 2003)	-	-	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 78% (combi boiler)	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer, room thermostat and TRVs	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 38mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£15)**	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	-	**£2,815**	-
Annual fuel cost savings	-	-	£58	-
Percentage annual fuel cost savings	-	-	15%	-
SAP Rating	C (79)	-	B (83)	-
EI Rating	B (84)	-	B (87)	-
Approximate CO_2 emissions $kg/m^2/year$	21	-	17	-
Percentage CO_2 improvement	-	-	19%	-

Case study H-22G: 1999-2007 mid-terrace (97m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £590				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	Insulation	-	-	-
Roof	200mm insulation (assumed)	-	250mm at joists **(£283)**	-
Windows	100% double glazing (post 2003)	-	-	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 78% (combi boiler)	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer, room thermostat and TRVs	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 38mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£18)**	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	-	**£3,101**	**£11,101**
Annual fuel cost savings	-	-	£107	£107
Percentage annual fuel cost savings	-	-	18%	18%
SAP Rating	C (75)	-	C (80)	B (85)
EI Rating	C (76)	-	B (81)	B (86)
Approximate CO_2 emissions kg/m^2/year	26	-	20	15
Percentage CO_2 improvement	-	-	23%	42%

Case study H-23G: 1999-2007 semi-detached (73m²)				
Fuel type: Gas				
Baseline annual fuel costs: £543				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	Insulation		-	-
Floor	Insulation	-	-	-
Roof	200mm insulation (assumed)	-	250mm at joists **(£283)**	-
Windows	100% double glazing (post 2003)	-	-	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 78% (combi boiler)	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer, room thermostat and TRVs	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 38mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	-	100% **(£18)**	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	-	**£3,101**	**£11,101**
Annual fuel cost savings	-	-	£93	£93
Percentage annual fuel cost savings	-	-	17%	17%
SAP Rating	C (73)	-	C (77)	B (82)
EI Rating	C (74)	-	C (79)	B (84)
Approximate CO_2 emissions kg/m²/year	31	-	25	20
Percentage CO_2 improvement	-	-	19%	35%

Annex H Modelling for Additional Case Studies

Hard-to-Treat Case studies 1 - 2: Pre 1919 solid wall flats

Case study HTT-1E: Pre 1919 solid wall dwelling - ground floor (2 bed) (109m^2) , gable end				
Fuel type: Electricity				
Baseline annual fuel costs: £1,636				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,768**	-	**£15,168**
Annual fuel cost savings	-	£406	-	£806
Percentage annual fuel cost savings	-	25%	-	49%
SAP Rating	E (44)	D (58)	-	C (72)
EI Rating	F (25)	F (34)	-	E (52)
Approximate CO_2 emissions kg/m^2/year	601	484	-	315
Percentage CO_2 improvement	-	23%	-	49%

Case study HTT-1G: Pre 1919 solid wall dwelling - ground floor (2 bed) (109m²), gable end				
Fuel type: Gas				
Baseline annual fuel costs: £1,416				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£3,718**	**£6,518**	**£16,918**
Annual fuel cost savings	-	£117	£539	£766
Percentage annual fuel cost savings	-	8%	38%	54%
SAP Rating	E (49)	E (53)	D (68)	C (77)
EI Rating	E (44)	E (47)	D (66)	C (76)
Approximate CO_2 emissions kg/m^2/year	346	318	202	140
Percentage CO_2 improvement	-	8%	41%	60%

The next two examples replicate the ground floor tenements of archetypes **HTT-1E and HTT-1G**, but use in-situ u-values instead of the default RdSAP u-values. They also use the actual costs for the floor and secondary glazing measures that were actually carried out on the archetype that HTT-1E and HTT-1G is based on.

The actual in-situ u-values for this archetype were 3.5 W/m^2K for the solid floor and 0.6 W/m^2K for the insulated floor. As RdSAP can only work within the range of 0.1 - 2.3 W/m^2K for a floor, 2.3 W/m^2K was selected for the actual baseline floor u-value. Compared to the default of 0.5 W/m^2K as calculated by RdSAP in the previous examples, 2.3 W/m^2K is still of poor thermal performance in comparison. The improved u-value of 0.6 W/m^2K was input for the insulated floor compared to 0.28 W/m^2K which is the default value for this floor with insulation of no specific thickness.

The single glazed windows had been tested in-situ and a u-value of 5.5 W/m^2K was measured. User defined u-values for windows can only be entered into RdSAP for multiple glazed windows. Therefore these were entered as double glazed in order to alter the u-value. However it was found that this u-value was out of range and the highest u-value accepted (5.1 W/m^2K) was selected. This closely compares to the default of 4.8 W/m^2K.

For window improvements secondary glazing with an in situ u-value of 2.3 W/m^2K was input, compared to 3.1 W/m^2K for pre-2003 double glazing and 2.0 W/m^2K for post 2003 double glazing.

The in-situ u-value of 1.4 W/m^2K for the sandstone wall was selected as compared to 2.0 W/m^2K for a sandstone wall with no unknown / default wall thickness. As there were no in situ wall insulation work carried out, this measure was kept as the default u-value of 0.6 W/m^2K.

The actual costs for floor insulation and secondary glazing were used. These costs were £9.434 for floor insulation and £5,040 for secondary glazing, compared to £1,200 and £3,700 used in HTT-1E and HTT-1G.

For these archetypes, the adjustments of the u-values make the expected thermal performance of this dwelling before and after improvements less efficient compared to the default assumptions. Similarly the costs for the measures are higher.

Case study HTT-1E: Pre 1919 solid wall dwelling - ground floor (2 bed), gable end (actual costs and u-values) ($109m^2$)				
Fuel type: Electricity				
Baseline annual fuel costs: £2,411				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	No insulation	-	-	Insulation **(£9,434*)**
Roof	-	-	-	-
Windows	100% single glazing	100% secondary glazing **(£5,040*)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£6,108**	-	**£21,042**
Annual fuel cost savings	-	£623	-	£1,447
Percentage annual fuel cost savings	-	26%	-	60%
SAP Rating	F (23)	E (39)	-	D (67)
EI Rating	G (8)	G (18)	-	E (45)
Approximate CO_2 emissions $kg/m^2/year$	902	718	-	370
Percentage CO_2 improvement	-	18%	-	58%
* - Actual costs of installation				

Case study HTT-1G: Pre 1919 solid wall dwelling - ground floor (2 bed), gable end (actual costs and u-values) (109m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,884				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	No insulation	-	-	Insulation **(£9,434*)**
Roof	-	-	-	-
Windows	100% single glazing	100% secondary glazing **(£5,040*)**	-	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£5,058**	**£7,858**	**£22,792**
Annual fuel cost savings	-	£113	£697	£1,155
Percentage annual fuel cost savings	-	6%	37%	61%
SAP Rating	F (33)	F (37)	D (57)	C (74)
EI Rating	F (31)	F (33)	E (52)	C (73)
Approximate CO_2 emissions kg/m^2/year	474	447	287	161
Percentage CO_2 improvement	-	6%	40%	66%
* - Actual costs of installation				

Case study HTT-2E: Pre 1919 solid wall dwelling - top floor (3 bed) (126m^2); gable end, partial flat roof				
Fuel type: Electricity				
Baseline annual fuel costs: £2,902				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	-	-	-	-
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)** and flat roof insulation **(£1,175)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£1,668**	**£6,826**	**£12,326**
Annual fuel cost savings	-	£970	£1,619	£1,940
Percentage annual fuel cost savings	-	33%	56%	67%
SAP Rating	G (19)	E (40)	D (60)	C (70)
EI Rating	G (5)	G (19)	F (37)	E (50)
Approximate CO_2 emissions kg/m^2/year	949	675	437	319
Percentage CO_2 improvement	-	29%	54%	66%

Case study HTT-2G: Pre 1919 solid wall dwelling - top floor (3 bed) (126m^2), gable end partial flat roof				
Fuel type: Gas				
Baseline annual fuel costs: £2,201				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	Internal insulation **(£5,500)**
Floor	-	-	-	-
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)** and flat roof insulation **(£1,175)**	-
Windows	100% single glazing	100% draughtproofing **(£100)**	100% double glazing (post 2003) **(£3,700)**	-
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£618**	**£8,576**	**£14,076**
Annual fuel cost savings	-	£284	£1,287	£1,469
Percentage annual fuel cost savings	-	13%	58%	67%
SAP Rating	F (31)	F (38)	C (70)	C (76)
EI Rating	F (28)	F (34)	D (68)	C (75)
Approximate CO_2 emissions kg/m^2/year	486	422	184	140
Percentage CO_2 improvement	-	17%	63%	72%

Hard-to-Treat case studies 3 – 4: System built Multi-storey flats 1950-64

Case study HTT-3E: System built Multi-storey flat 1950-64 - ground floor gable end (2 bed) ($69m^2$)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,012				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,765**	**£10,265**	**£15,165**
Annual fuel cost savings	-	£250	£288	£555
Percentage annual fuel cost savings	-	25%	28%	55%
SAP Rating	E (53)	D (65)	C (74)	C (79)
EI Rating	F (33)	E (43)	D (57)	D (66)
Approximate CO_2 emissions $kg/m^2/year$	575	461	324	258
Percentage CO_2 improvement	-	20%	44%	55%

Case study HTT-3G: System built Multi-storey flat 1950-64 - ground floor gable end (electric - gas community heating) (2 bed) (69m^2)				
Fuel type: Electricity - Gas				
Baseline annual fuel costs: £1,012				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation**(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Gas communal heating **(£12,209*)**	-	-
Heating system controls	Manual charge control	Flat rate charging, programmer and TRVs **(included in communal heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	From communal heating with 80mm factory applied foam **(included in communal heating costs)**	-	-
Secondary space heating	Electric room heater	None	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£15,924**	**£21,424**	**£26,324**
Annual fuel cost savings	-	£350	£486	£563
Percentage annual fuel cost savings	-	35%	48%	56%
SAP Rating	E (53)	D (68)	C (75)	C (78)
EI Rating	F (33)	D (65)	C (75)	C (79)
Approximate CO_2 emissions kg/m^2/year	575	240	174	144
Percentage CO_2 improvement	-	55%	68%	73%
* - Actual costs of installation (includes energy centre built out-with building)				

Case study HTT-4E: System built Multi-storey flat 1950-64 - mid floor gable end (2 bed) ($69m^2$)

Fuel type: Electricity

Baseline annual fuel costs: £808

Energy Efficiency Measure	Baseline: 1990	SHQS 2015	Further Measures 2020	Advanced Measures 2050
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,765**	**£10,265**	**£13,965**
Annual fuel cost savings	-	£212	£431	£466
Percentage annual fuel cost savings	-	26%	53%	58%
SAP Rating	D (63)	C (72)	B (83)	B (84)
EI Rating	E (44)	E (54)	C (73)	C (76)
Approximate CO_2 emissions $kg/m^2/year$	449	351	206	182
Percentage CO_2 improvement	-	22%	55%	60%

Case study HTT-4G: System built Multi-storey flat 1950-64 - mid floor gable end (electric - gas community heating) (2 bed) (69m²)				
Fuel type: Electricity - Gas				
Baseline annual fuel costs: £808				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Gas communal heating **(£12,209*)**	-	-
Heating system controls	Manual charge control	Flat rate charging, programmer and TRVs **(included in communal heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	From communal heating with 80mm factory applied foam **(included in communal heating costs)**	-	-
Secondary space heating	Electric room heater	None	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£15,924**	**£21,424**	**£25,124**
Annual fuel cost savings	-	£262	£411	£445
Percentage annual fuel cost savings	-	32%	51%	55%
SAP Rating	D (63)	C (73)	B (81)	B (82)
EI Rating	E (44)	C (73)	B (83)	B (85)
Approximate CO_2 emissions kg/m²/year	449	187	117	105
Percentage CO_2 improvement	-	55%	71%	75%
* - Actual costs of installation (includes energy centre built out-with building)				

Hard-to-treat case studies 5 - 8 - System built flats 1950-64

Case study HTT-5E: 1950-64 System built external deck access flat, ground floor gable end (2 bed) ($58m^2$)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,082				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,765**	**£10,265**	**£15,165**
Annual fuel cost savings	-	£273	£535	£635
Percentage annual fuel cost savings	-	25%	49%	59%
SAP Rating	E (45)	D (59)	C (72)	C (77)
EI Rating	F (26)	F (36)	E (54)	D (63)
Approximate CO_2 emissions $kg/m^2/year$	730	581	377	299
Percentage CO_2 improvement	-	21%	48%	60%

Case study HTT-5G: 1950-64 System built external deck access flat, ground floor gable end (2 bed) ($58m^2$)				
Fuel type: Gas				
Baseline annual fuel costs: £983				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£3,715**	**£9,215**	**£14,115**
Annual fuel cost savings	-	£74	£503	£568
Percentage annual fuel cost savings	-	8%	51%	58%
SAP Rating	E (47)	E (51)	C (75)	C (78)
EI Rating	E (44)	E (48)	C (77)	B (81)
Approximate CO_2 emissions kg/m^2/year	425	392	171	142
Percentage CO_2 improvement	-	8%	61%	67%

Case study HTT-6E: 1950-64 System built external deck access flat, mid floor gable end (2 bed) ($67m^2$)				
Fuel type: Electricity				
Baseline annual fuel costs: £835				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,765**	**£10,265**	**£13,965**
Annual fuel cost savings	-	£212	£460	£493
Percentage annual fuel cost savings	-	25%	55%	59%
SAP Rating	D (61)	C (70)	B (82)	B (84)
EI Rating	E (41)	E (51)	C (72)	C (75)
Approximate CO_2 emissions $kg/m^2/year$	486	385	216	190
Percentage CO_2 improvement	-	21%	56%	61%

Case study HTT-6G: 1950-64 System built external deck access flat, mid floor gable end (2 bed) (67m²)				
Fuel type: Gas				
Baseline annual fuel costs: £836				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	-	-	-	-
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£3,718**	**£9,218**	**£12,918**
Annual fuel cost savings	-	£90	£452	£480
Percentage annual fuel cost savings	-	11%	54%	57%
SAP Rating	D (58)	D (62)	B (81)	B (82)
EI Rating	D (55)	D (60)	B (84)	B (86)
Approximate CO_2 emissions kg/m²/year	310	275	109	100
Percentage CO_2 improvement	-	13%	65%	68%

The No Fines archetypes (**HTT-7E, HTT-7G, HTT-8E and HTT-8G**) have been modelled using actual u-values based on drawings of the building's construction. Improved u-values were calculated based on insulation specification.

- The main walls were calculated as having a u-value of 1.53 W/m^2K and 0.713 W/m^2K when improved by installing 75mm of external insulation cladding.
- The sheltered wall was calculated as having a u-value of 0.923 W/m^2K and 0.546 W/m2K when improved by installing 75mm of external insulation cladding.
- The floors when improved were calculated to have a u-value of 0.302 W/m^2K.

These have been modelled here with all the default values

- 2.0 W/m^2K for the main walls and 0.6 W/m^2K when improved
- the sheltered wall as 1.11 W/m^2K and 0.48 W/m^2K when improved
- The floors of the ground floor archetype (HTT-7) are defaulted as having an improved u-value of 0.34 W/m^2K.

In this instance the baseline “user defined” fabric performance of the dwelling is greater than the default assumptions and have better results. However, when the improvements are modelled, the improved fabric performance is marginally poorer than the default assumed improved settings. Therefore, the default results are slightly better when the fabric improvements are modelled.

Case study HTT-7E: 1950-1964 No Fines concrete flat (2 bed) - ground floor, gable end (user defined u-values) ($65m^2$)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,099				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	External insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,765**	**£10,265**	**£15,165**
Annual fuel cost savings	-	£251	£420	£531
Percentage annual fuel cost savings	-	23%	38%	48%
SAP Rating	E (47)	D (59)	D (67)	C (73)
EI Rating	F (28)	F (36)	E (46)	E (54)
Approximate CO_2 emissions $kg/m^2/year$	676	557	433	357
Percentage CO_2 improvement	-	18%	36%	47%

Case study HTT-7G: 1950-64 No Fines concrete flat (2 bed) - ground floor, gable end (user defined u-values) (65m²)				
Fuel type: Gas				
Baseline annual fuel costs: £1,003				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	External insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£3,718**	**£12,018**	**£16,918**
Annual fuel cost savings	-	£78	£446	£524
Percentage annual fuel cost savings	-	8%	44%	52%
SAP Rating	E (49)	E (53)	C (72)	C (76)
EI Rating	E (46)	E (49)	C (73)	C (78)
Approximate CO_2 emissions kg/m²/year	397	365	191	159
Percentage CO_2 improvement	-	8%	52%	60%

Case study HTT-7E: 1950-1964 No Fines concrete flat (2 bed) - ground floor, gable end (default u-values) (65m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,224				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	External insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,765**	**£10,265**	**£15,165**
Annual fuel cost savings	-	£307	£563	£683
Percentage annual fuel cost savings	-	25%	46%	56%
SAP Rating	E (41)	D (56)	D (68)	C (74)
EI Rating	F (23)	F (32)	E (48)	D (57)
Approximate CO_2 emissions kg/m^2/year	758	606	421	338
Percentage CO_2 improvement	-	21%	45%	55%

Case study HTT-7G: 1950-64 No Fines concrete flat (2 bed) - ground floor, gable end (default u-values) ($65m^2$)				
Fuel type: Gas				
Baseline annual fuel costs: £1,079				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	External insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	-	-	-	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£3,718**	**£12,018**	**£16,918**
Annual fuel cost savings	-	£77	£532	£608
Percentage annual fuel cost savings	-	7%	49%	56%
SAP Rating	E (45)	E (49)	C (73)	C (76)
EI Rating	E (42)	E (45)	C (74)	C (78)
Approximate CO_2 emissions $kg/m^2/year$	432	401	186	155
Percentage CO_2 improvement	-	7%	57%	65%

Case study HTT-8E: 1950-64 No Fines concrete flat (2 bed) - top floor, gable end (user defined u-values) (65m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,533				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	External insulation **(£5,500)**	-
Floor	-	-	-	-
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£5,265**	**£11,048**	**£14,748**
Annual fuel cost savings	-	£787	£982	£1,017
Percentage annual fuel cost savings	-	51%	64%	66%
SAP Rating	F (29)	D (64)	C (74)	C (75)
EI Rating	G (13)	E (42)	D (56)	D (59)
Approximate CO_2 emissions $kg/m^2/year$	963	484	344	320
Percentage CO_2 improvement	-	49%	65%	66%

Case study HTT-8G: 1950-1964 No Fines concrete flat (2 bed) - top floor, gable end (user defined u-values) (65m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,253				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	External insulation **(£5,500)**	-
Floor	-	-	-	-
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,218**	**£12,801**	**£16,501**
Annual fuel cost savings	-	£398	£785	£797
Percentage annual fuel cost savings	-	32%	63%	64%
SAP Rating	F (37)	D (56)	C (77)	C (77)
EI Rating	F (35)	E (53)	C (79)	C (79)
Approximate CO_2 emissions kg/m^2/year	512	333	150	149
Percentage CO_2 improvement	-	34%	70%	72%

Case study HTT-8E: 1950-1964 No Fines concrete flat (2 bed) - top floor, gable end (default u-values) (65m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,676				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	External insulation **(£5,500)**	-
Floor	-	-	-	-
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£5,265**	**£11,048**	**£14,748**
Annual fuel cost savings	-	£825	£1,142	£1,176
Percentage annual fuel cost savings	-	49%	68%	70%
SAP Rating	F (25)	D (59)	C (74)	C (76)
EI Rating	G (9)	F (36)	D (57)	D (60)
Approximate CO_2 emissions kg/m²/year	1057	558	332	309
Percentage CO_2 improvement	-	47%	68%	71%

Case study HTT-8G: 1950-1964 No Fines concrete flat (2 bed) - top floor, gable end (default u-values) (65m²)				
Fuel type: Gas				
Baseline annual fuel costs: £1,325				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	External insulation **(£5,500)**	-
Floor	-	-	-	-
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£15)**	-	-
Solar PVs	None	-	-	-
Total cost of all measures applied since baseline	-	**£4,218**	**£12,801**	**£16,501**
Annual fuel cost savings	-	£379	£851	£877
Percentage annual fuel cost savings	-	29%	64%	66%
SAP Rating	F (34)	E (52)	C (76)	C (77)
EI Rating	F (32)	E (48)	C (78)	C (80)
Approximate CO_2 emissions $kg/m^2/year$	546	375	153	145
Percentage CO_2 improvement	-	31%	72%	74%

Case studies 9 - 12 – Concrete, Steel frame and timber houses

The following Swedish timber archetype (**HTT-9E and HTT-9G)** use u-values based on actual wall construction and u-value calculations and make comparisons against the default values in RdSAP.

The user defined u-values of the main wall were calculated using record drawings of the wall construction and specification of insulation materials. Either external or internal wall insulation could be applied. The improved u-value could be obtained from either insulation method. The u-values modelled were: 1.241 W/m^2K (pre) / 0.253 W/m^2K (post).

These were compared against the default u-values for system built 2.0 W/m^2K (pre) and the default unknown wall insulation of 0.6 W/m^2K (post). Where the previous example used 150mm floor ins to obtain a u-value of 0.17 W/m^2K, based on specifications, these examples use the default unknown retro floor insulation and gives the u-value of 0.35 W/m^2K.

For this case study the fabric performance of the dwelling before and after improvements is greater than the default assumptions built into RdSAP. The RdSAP results are therefore better for this particular archetype by using details of the actual property's characteristics.

Case study HTT-9E: Swedish timer frame semi-detached (3 bed - 1946) (user defined u-values) (90m^2)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,919				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	Internal or external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,268**	**£10,768**	**£19,968**
Annual fuel cost savings	-	£881	£1,148	£1,238
Percentage annual fuel cost savings	-	46%	60%	65%
SAP Rating	F (29)	D (59)	C (70)	C (79)
EI Rating	G (13)	F (36)	E (50)	D (60)
Approximate CO_2 emissions kg/m^2/year	872	494	353	284
Percentage CO_2 improvement	-	44%	60%	68%

Case study HTT-9G: Swedish timer frame semi-detached (3 bed - 1946) (user defined u-values) (90m²)				
Fuel type: Gas				
Baseline annual fuel costs: £1,559				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	Internal or external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£4,218**	**£12,801**	**£25,701**
Annual fuel cost savings	-	£342	£903	£993
Percentage annual fuel cost savings	-	22%	58%	64%
SAP Rating	F (37)	E (50)	C (73)	B (82)
EI Rating	F (34)	E (45)	C (73)	B (82)
Approximate CO_2 emissions kg/m²/year	470	360	169	116
Percentage CO_2 improvement	-	23%	64%	75%

Case study HTT-9E: Swedish timer frame semi-detached (3 bed - 1946) (default u-values) (90m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £2,189				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	Internal or external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,265**	**£10,765**	**£19,965**
Annual fuel cost savings	-	£956	£1,317	£1,377
Percentage annual fuel cost savings	-	44%	60%	63%
SAP Rating	F (22)	E (52)	D (66)	C (73)
EI Rating	G (7)	F (28)	E (44)	E (51)
Approximate CO_2 emissions $kg/m^2/year$	1001	594	404	351
Percentage CO_2 improvement	-	41%	60%	65%

Case study HTT-9G: Swedish timer frame semi-detached (3 bed - 1946) (default u-values) ($90m^2$)				
Fuel type: Gas				
Baseline annual fuel costs: £1,700				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	Internal or external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£4,218**	**£12,801**	**£25,701**
Annual fuel cost savings	-	£322	£989	£1,061
Percentage annual fuel cost savings	-	19%	58%	62%
SAP Rating	F (32)	E (43)	C (71)	C (79)
EI Rating	F (30)	E (39)	C (70)	C (78)
Approximate CO_2 emissions $kg/m^2/year$	517	414	187	141
Percentage CO_2 improvement	-	20%	64%	72%

Case study HTT-10E: 1950-1982 Timber frame semi-detached (3 bed - late 1960 / early 1970s) ($92m^2$)				
Fuel type: Electricity				
Baseline annual fuel costs: £1,633.50				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	12mm insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,268**	-	**£14,468**
Annual fuel cost savings	-	£761	-	£813
Percentage annual fuel cost savings	-	47%	-	50%
SAP Rating	E (41)	D (66)	-	C (74)
EI Rating	F (22)	E (45)	-	E (51)
Approximate CO_2 emissions $kg/m^2/year$	682	399	-	346
Percentage CO_2 improvement	-	41%	-	49%

Case study HTT-10G: 1950-1982 Timber frame semi-detached (3 bed - late 1960 / early 1970s) (92m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,354				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	-	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	12mm insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£4,218**	**£7,301**	**£20,201**
Annual fuel cost savings	-	£279	£650	£710
Percentage annual fuel cost savings	-	21%	48%	52%
SAP Rating	E (45)	D (56)	C (71)	C (79)
EI Rating	E (41)	E (51)	C (71)	C (78)
Approximate CO_2 emissions kg/m^2/year	393	306	185	139
Percentage CO_2 improvement	-	23%	53%	64%

Case study HTT-11E: System built concrete semi-detached house (Orlit - 3 bed - 1930-49) ($104m^2$)				
Fuel type: Electricity				
Baseline annual fuel costs: £2,347				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,265**	**£10,765**	**£19,965**
Annual fuel cost savings	-	£1,020	£1,511	£1,575
Percentage annual fuel cost savings	-	43%	64%	67%
SAP Rating	F (23)	E (54)	C (71)	C (78)
EI Rating	G (8)	F (30)	E (51)	D (59)
Approximate CO_2 emissions $kg/m^2/year$	925	543	331	279
Percentage CO_2 improvement	-	41%	64%	70%

Case study HTT-11G: System built concrete semi-detached house (Orlit - 3 bed - 1930-49) (104m²)				
Fuel type: Gas				
Baseline annual fuel costs: £1,832				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-	-
Heating system controls	Programmer	Time and temperature zone controls **(£300)**	-	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£7,018**	**£12,801**	**£25,701**
Annual fuel cost savings	-	£862	£1,136	£1,215
Percentage annual fuel cost savings	-	47%	62%	66%
SAP Rating	F (33)	D (64)	C (75)	B (82)
EI Rating	F (31)	D (60)	C (74)	B (82)
Approximate CO_2 emissions $kg/m^2/year$	483	239	157	111
Percentage CO_2 improvement	-	51%	68%	76%

Case study HTT-12E: System built steel frame semi–detached house (BISF - 3 bed - 1930-49) (89m²)				
Fuel type: Electricity				
Baseline annual fuel costs: £2,108				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	250mm at joists **(£500)**	-	-
Windows	100% single glazing	100% double glazing (post 2003) **(£3,700)**	-	-
Open chimneys	None	-	-	-
Heating system	Old (large volume) storage heaters	Fan storage heaters **(£1,050)**	-	-
Heating system controls	Manual charge control	Automatic charge control **(included in storage heating costs)**	-	-
Hot water system	Electric immersion with 25mm factory applied foam	Electric immersion with 80mm factory applied foam **(included in storage heating costs)**	-	-
Secondary space heating	Electric room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£5,265**	**£10,765**	**£19,965**
Annual fuel cost savings	-	£905	£1,360	£1,418
Percentage annual fuel cost savings	-	43%	65%	67%
SAP Rating	F (23)	E (53)	C (71)	C (78)
EI Rating	G (8)	F (30)	E (51)	D (59)
Approximate CO_2 emissions kg/m²/year	970	576	345	291
Percentage CO_2 improvement	-	39%	64%	69%

Case study HTT-12G: System built steel frame semi-detached house (BISF - 3 bed - 1930-49) (89m^2)				
Fuel type: Gas				
Baseline annual fuel costs: £1,653				
Energy Efficiency Measure	**Baseline: 1990**	**SHQS 2015**	**Further Measures 2020**	**Advanced Measures 2050**
Walls	No insulation	-	100mm external insulation **(£5,500)**	-
Floor	No insulation	-	-	Insulation **(£1,200)**
Roof	No insulation	100mm at joists **(£500)**	250mm at joists **(£283)**	-
Windows	100% single glazing	100% double glazing (pre 2003) **(£3,700)**	-	100% double glazing (post 2003) **(£3,700)**
Open chimneys	None	-	-	-
Heating system	Full central heating, boiler efficiency 66%	-	Full central heating, boiler efficiency 90% (condensing combi) **(£2,500)**	-
Heating system controls	Programmer	-	Time and temperature zone controls **(£300)**	-
Hot water system	Cylinder thermostat with 25mm factory applied foam	-	-	-
Secondary space heating	Gas room heater	-	-	-
Ventilation	natural	-	-	-
Low energy lighting	None	100% **(£18)**	-	-
Solar PVs	None	-	-	20% of roof area **(£8,000)**
Total cost of all measures applied since baseline	-	**£7,018**	**£12,801**	**£25,701**
Annual fuel cost savings	-	£761	£1,014	£1,086
Percentage annual fuel cost savings	-	46%	61%	66%
SAP Rating	F (33)	D (63)	C (74)	B (81)
EI Rating	F (31)	D (60)	C (74)	B (82)
Approximate CO_2 emissions kg/m^2/year	506	254	165	118
Percentage CO_2 improvement	-	49%	68%	77%

Appendix I Summary – Upgrade Measures and Outcomes

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
			EE	EI	EE	EI	EE	EI	EE	EI	SHQS	EESSH	2050
A: Pre 1919 solid wall dwelling	1: ground floor	Gas	E (51)	E (49)	D (56)	E (53)	C (71)	C (72)	C (76)	C (79)	–dbl glazing (pre 2003) –CLFs	–Boiler / controls	–int. wall ins. –floor ins. –dbl glazing (post 2003)
		Electric	E (52)	F (33)	D (65)	E (42)	N/A	N/A	C (74)	D (57)	–dbl glazing (pre 2003) –St. heating, controls & HWT –CFLs	–N/A	–int. wall ins –Floor ins –dbl glazing (post 2003)
A: Pre 1919 solid wall dwelling	2: mid floor	Gas	D (59)	D (57)	D (63)	D (62)	C (75)	C (78)	C (80)	B (83)	–dbl glazing (pre 2003) –CLFs	–Boiler / controls	–int. wall ins –dbl glazing (post 2003)
		Electric	D (64)	E (43)	C (72)	E (53)	N/A	N/A	C (80)	C (69)	–dbl glazing (pre 2003), –St. heating, controls & HWT –CFLs	–N/A	–int. wall ins –dbl glazing (post 2003)
A: Pre 1919 solid wall dwelling	3: top floor	Gas	E (40)	F (38)	D (62)	D (59)	C (76)	C (78)	C (79)	B (82)	–LI (100mm) –dbl glazing (pre 2003) –CFLs	–LI (250mm) –boiler / controls	–dbl glazing (post 2003) –int. wall ins.

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
		Electric	F (35)	G (18)	D (67)	E (46)	C (74)	D (57)	C (79)	D (66)	–LI (100mm) –St. heating, controls & HWT –CFLs	–LI (250mm) –dbl glazing (post 2003)	–int. wall ins.
B: 1930-49	4: mid-floor flat	Gas	D (64)	D (63)	C (71)	C (70)	B (82)	B (86)	N/A	N/A	–CWI –CFLs	–dbl glazing (post 2003) –boiler / controls	–N/A
		Electric	D (68)	E (50)	C (79)	D (68)	B (81)	C (71)	B (83)	C (74)	–CWI –dbl glazing (pre 2003) –CFLs	–St. heating, controls & HWT	–dbl glazing (post 2003)
B: 1930-49	5: mid-terrace	Gas	E (42)	E (39)	D (62)	D (59)	C (76)	C (76)	B (83)	B (84)	–CWI –LI (100mm) –dbl glazing (pre 2003) –CFLs	–LI (250mm) –boiler / controls	–floor ins –dbl glazing (post 2003) –PV
		Electric	F (36)	G (19)	C (73)	D (55)	N/A	N/A	C (80)	D (63)	–CWI –LI (250mm) –dbl glazing (pre 2003) –St. heating, controls & HWT –CFLs	–N/A	–floor ins –PV

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
B: 1930-49	6: semi-detached	Gas	F (36)	F (33)	D (59)	E (54)	C (74)	C (74)	B (81)	B (81)	–CWI –LI (100mm) –dbl glazing (pre 2003) –CFLs	–LI (250mm) –boiler / controls	–floor ins –dbl glazing (post 2003) –PV
		Electric	F (27)	G (11)	C (69)	E (47)	N/A	N/A	C (76)	D (55)	–CWI –LI (250mm) –dbl glazing (pre 2003) –St. heating, controls & HWT –CFLs	–N/A	–floor ins –PV
C: 1930-49	7: Four-in-a-block lower	Gas	E (50)	E (46)	D (61)	D (56)	C (74)	C (74)	C (78)	C (79)	–CWI –CFLs	–boiler / controls	–floor ins –dbl glazing (post 2003)
		Electric	E (47)	F (28)	C (71)	E (51)	N/A	N/A	C (75)	D (57)	–CWI –dbl glazing (post 2003) –St. heatIng /controls /HWT –CFLs	–N/A	–floor ins
C: 1930-49	8: Four-in-a-block upper	Gas	F (34)	F (32)	D (61)	D (57)	C (76)	C (77)	B (89)	B (89)	–CWI –LI (100mm) –CFLs	–LI (250mm) –boiler /controls	–dbl glazing (post 2003) –PV

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
		Electric	F (25)	G (9)	C (70)	E (52)	C (74)	D (56)	B (85)	D (66)	–CWI –LI (250mm) –dbl glazing (pre 2003) –CFLs	–St. heater /controls /HWT	–PV
D: 1950-65 post war	9: mid-floor flat	Gas	D (67)	D (65)	C (74)	C (73)	B (81)	B (83)	B (84)	B (86)	–CWI –CFLs	–boiler /controls	–dbl glazing (post 2003)
		Electric	C (69)	E (52)	C (77)	D (64)	B (84)	C (75)	N/A	N/A	–CWI –CFLs	–dbl glazing (post 2003) –St. heater /controls /HWT	–N/A
D: 1950-65 post war	10: mid-terrace	Gas	E (44)	E (41)	D (60)	D (56)	C (74)	C (75)	B (82)	B (84)	–CWI –LI (100mm) –CFLs	–LI (250mm) –boiler / controls	–floor ins –dbl glazing (post 2003) –PV
		Electric	E (40)	F (22)	C (72)	E (54)	N/A	N/A	C (80)	D (64)	–CWI –LI –Dbl glazing (pre 2003) –St. heater /controls /HWT –CFLs	–N/A	–floor ins –dbl glazing (post 2003) –PV
D: 1950-65 post war	11: semi-detached	Gas	F (33)	F (30)	E (53)	E (48)	C (70)	C (69)	C (79)	C (79)	–CWI –LI (100mm) –CFLs	–LI (250mm) –boiler / controls	–floor ins –dbl glazing (post 2003) –PV

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
		Electric	F (22)	G (7)	C (71)	E (45)	N/A	N/A	C (73)	E (51)	–CWI –LI –dbl glazing (post 2003) –St. heater /controls /HWT –CFLs –PV	–N/A	–floor ins
E: 1976-83	12: mid-floor flat	Gas	D (66)	D (66)	C (71)	C (71)	B (82)	B (86)	N/A	N/A	–CWI –CFLs	–dbl glazing (post 2003) –Boilers / controls	–N/A
		Electric	C (72)	D (58)	C (78)	D (65)	B (84)	C (77)	N/A	N/A	–CWI –CFLs	–dbl glazing (post 2003) –St. heater /controls /HWT	–N/A
E: 1976-83	13: mid-terrace	Gas	E (47)	E (43)	D (56)	E (51)	C (75)	C (76)	B (81)	B (82)	–CWI –LI (100mm) –CFLs	–LI (250mm) –dbl glazing (post 2003) –boiler / controls	–floor ins –PV
		Electric	E (44)	F (25)	D (66)	E (45)	D (68)	E (47)	C (77)	D (58)	–CWI –LI (100mm) –dbl glazing (pre 2003) –St. heater / controls –CFLs	–LI (250mm)	–floor ins, –dbl glazing (post 2003), –HWT –PV

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
E: 1976-83	14: semi-detached	Gas	E (47)	E (42)	D (60)	D (55)	C (75)	C (74)	B (82)	B (82)	–CWI –LI (100mm) –CFLs	–LI (250mm) –boiler / controls	–floor ins –dbl glazing (post 2003) –PV
		Electric	E (42)	F (24)	D (69)	E (49)	N/A	N/A	C (77)	D (57)	–CWI –LI (250mm) –dbl glazing (post 2003) –St. heater /controls /HWT –CFLs	–N/A	–floor ins –PV
F: 1984-91	15: mid-floor flat	Gas	C (71)	C (73)	N/A	N/A	B (81)	B (86)	N/A	N/A	–N/A	–dbl glazing (Post 2003) –boiler / controls –CFLs	–N/A
		Electric	C (79)	C (69)	N/A	N/A	B (82)	C (72)	B (85)	C (70)	–N/A	–St. heater/ HWT –CFLs	–additional wall ins –dbl glazing (post 2003)
F: 1984-91	16: mid-terrace	Gas	D (59)	D (55)	N/A	N/A	C (76)	C (77)	C (80)	B (81)	–N/A	–LI (250mm) –dbl glazing (Post 2003) –boiler / controls	–PV
		Electric	D (63)	E (44)	C (70)	E (49)	N/A	N/A	C (77)	D (57)	–LI (250mm) –St. heater / HWT –CFLs	–N/A	–dbl glazing (post 2003) –PV

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
F: 1984-91	17: semi-detached	Gas	E (52)	E (48)	N/A	N/A	C (72)	C (72)	C (76)	C (76)	– N/A	– LI (250mm) – dbl glazing (Post 2003) – boiler / controls – CFLs	– PV
		Electric	E (51)	F (32)	D (67)	E (42)	C (69)	E (45)	C (71)	E (48)	– LI (250mm) – St. heater /controls / HWT – CFLs – PV	– dbl glazing (post 2003)	– SHW
G: 1992-98	18: mid-floor flat	Gas	C (69)	C (69)	N/A	N/A	C (80)	B (83)	N/A	N/A	– N/A	– dbl glazing (Post 2003) – boiler / controls – CFLs	– N/A
		Electric	C (76)	D (64)	N/A	N/A	C (80)	C (69)	N/A	N/A	– N/A	– St. heater/ HWT – CFLs	– N/A
G: 1992-98	19: mid-terrace	Gas	D (65)	D (64)	N/A	N/A	C (76)	C (77)	B (81)	B (83)	– N/A	– LI (250mm) – boiler / controls – CFLs	– dbl glazing (Post 2003) – PV
		Electric	D (65)	E (47)	C (74)	E (54)	C (78)	D (60)	N/A	N/A	– LI (100-250mm) – CFLs – PV	– dbl glazing (post 2003) – St. heater /HWT	– N/A

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
G: 1992-98	20: semi-detached	Gas	D (61)	D (58)	N/A	N/A	C (73)	C (73)	C (78)	C (79)	–N/A	–LI (100-250mm) –boiler / controls –CFLs	–dbl glazing (Post 2003) –PV
		Electric	D (59)	E (39)	D (67)	E (45)	C (72)	E (50)	N/A	N/A	–LI (100-250mm) –CFLs –PV	–dbl glazing (post 2003) –St. heater /HWT	–N/A
H: 1999-2007	21: mid-floor flat	Gas	C (79)	B (84)	N/A	N/A	B (83)	B (87)	N/A	N/A	–N/A	–Boiler / controls –CFLs	–N/A
		Electric	B (81)	C (74)	N/A	N/A	B (84)	C (77)	N/A	N/A	–N/A	–St. heater / controls / HWT –CFLs	–N/A
H: 1999-2007	22: mid-terrace	Gas	C (75)	C (76)	N/A	N/A	C (80)	B (81)	B (85)	B (86)	–N/A	–LI (200-250mm top-up) –boiler / controls –CFLs	–PV
		Electric	C (73)	D (57)	N/A	N/A	C (77)	D (60)	B (82)	D (65)	–N/A	–LI (200-250mm top-up) –St. heater / HWT –CFLs	–PV

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
H: 1999-2007	23: semi-detached	Gas	C (73)	C (74)	N/A	N/A	C (77)	C (79)	B (82)	B (84)	– N/A	– LI (200-250mm top-up) – boiler / controls – CFLs	– PV
		Electric	C (70)	E (53)	N/A	N/A	C (74)	D (56)	C (79)	D (60)	– N/A	– LI (200-250mm top-up) – St. heater / HWT – CFLs	– PV
HTT-Pre-1919 tenement flat	1: Ground floor, gable end	Gas	E (49)	E (44)	E (53)	E (47)	D (68)	D (66)	C (77)	C (76)	– Dbl glazing (pre-2003) – CFLs	– Boiler / controls	– Int. wall ins. – Floor ins. – Dbl. glazing (post 2003)
		Electric	E (44)	F (25)	D (58)	F (34)	N/A	N/A	C (72)	E (52)	– Dbl glazing (pre-2003) – St. heating/ controls/ HWT – CFLs	– N/A	– Int. wall ins. – Floor ins. – Dbl. glazing (post 2003)
HTT: Pre-1919 tenement flat	1: Ground floor, gable end (in-situ	Gas	F (33)	F (31)	F (37)	F (33)	D (57)	E (52)	C (74)	C (73)	– Sec. glazing – CFLs	– Boiler / controls	– Int. wall ins. – Floor ins.

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
	u-values)	Electric	F (23)	G (8)	E (39)	G (18)	N/A	N/A	D (67)	E (45)	– Sec. glazing – St. heating, controls & HWT – CFLs	– N/A	– Int. wall ins. – Floor ins.
HTT: Pre-1919 tenement flat	2: Top floor, gable end, partial flat roof	Gas	F (31)	F (28)	F (38)	F (34)	C (70)	D (68)	C (76)	C (75)	– LI (100mm) – Draught proofing – CFLs	– LI (250mm) – flat roof ins. – Boiler /controls – dbl glazing (post 2003)	– Int. wall ins
		Electric	G (19)	G (5)	E (40)	G (19)	D (60)	F (37)	C (70)	E (50)	– LI (100mm) – St. heating, controls & HWT – Draught proofing – CFLs	– LI (250mm) – flat roof ins – dbl glazing (post 2003)	– Int. wall ins
HTT: Multi-storey flat	3: Ground floor, gable end	Gas	E (53)	F (33)	D (68)	D (65)	C (75)	C (75)	C (78)	C (79)	– communal gas heating (ext.) – dbl glazing (pre 2003) – CFLs	– ext. wall ins (100mm)	– floor ins. – dbl glazing (post 2003)

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
		Electric	E (53)	F (33)	D (65)	E (43)	C (74)	D (57)	C (79)	D (66)	– Dbl glazing (pre 2003) – St. heating, controls & HWT – CFLs	– ext. wall ins (100mm)	– floor ins. – dbl glazing (post 2003)
HTT: Multi-storey flat	4: Mid-floor, gable end	Gas	D (63)	E (44)	C (73)	C (73)	B (81)	B (83)	B (82)	B (85)	– communal gas heating (ext.) – dbl glazing (pre 2003) – CFLs	– ext. wall ins (100mm)	– dbl glazing (post 2003)
		Electric	D (63)	E (44)	C (72)	E (54)	B (83)	C (73)	B (84)	C (76)	– Dbl glazing (pre 2003) – St. heating, controls & HWT – CFLs	– ext. wall ins (100mm)	– dbl glazing (post 2003)
HTT: External deck access flat	5: Ground floor, gable end	Gas	E (47)	E (44)	E (51)	E (48)	C (75)	C (77)	C (78)	B (81)	– dbl glazing (pre 2003) – CFLs	– Boiler / controls – ext. wall ins (100mm)	– floor ins – dbl glazing (post 2003)

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
		Electric	E (45)	F (26)	D (59)	F (36)	C (72)	E (54)	C (77)	D (63)	– dbl glazing (pre 2003) – St. heating, controls & HWT – CFLs	– ext. wall ins (100mm)	– floor ins – dbl glazing (post 2003)
HTT: External deck access flat	6: Mid-floor, gable end	Gas	D (58)	D (55)	D (62)	D (60)	B (81)	B (84)	B (82)	B (86)	– dbl glazing (pre 2003) – CFLs	– Boiler/controls – ext. wall ins (100mm)	– dbl glazing (post 2003)
		Electric	D (61)	E (41)	C (70)	E (51)	B (82)	C (72)	B (84)	C (75)	– dbl glazing (pre 2003) – St. heating, controls & HWT – CFLs	– ext. wall ins (100mm)	– dbl glazing (post 2003)
HTT: No Fines concrete flat	7: Ground floor, gable end (user defined u-values)	Gas	E (49)	E (46)	E (53)	E (49)	C (72)	C (73)	C (76)	C (78)	– Dbl glazing (pre-2003) – CFLs	– Boiler / controls – ext. wall ins.	– Floor ins. – Dbl glazing (post-2003)
		Electric	E (47)	F (28)	D (59)	F (36)	D (67)	E (46)	C (73)	E (54)	– Dbl glazing (pre-2003) – St. heating, controls, HWT – CFLs	– ext. wall ins.	– Floor ins. – Dbl glazing (post-2003)

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
HTT: No Fines concrete flat	7: Ground floor, gable end (default u-values)	Gas	E (45)	E (42)	E (49)	E (45)	C (73)	C (74)	C (76)	C (78)	– Dbl glazing (pre-2003) – CFLs	– Boiler / controls – ext. wall ins.	– Floor ins. – Dbl glazing (post-2003)
		Electric	E (41)	F (23)	D (56)	F (32)	D (68)	E (48)	C (74)	D (57)	– Dbl glazing (pre-2003) – St. heating, controls, HWT – CFLs	– ext. wall ins.	– Floor ins. – Dbl glazing (post-2003)
HTT: No Fines concrete flat	8: Top floor, gable end (user defined u-values)	Gas	F (37)	F (35)	D (56)	E (53)	C (77)	C (79)	C (77)	C (79)	– dbl glazing (pre 2003) – Loft ins. (100mm) – CFLs	– loft ins. (250mm) – Boiler/ controls Ext. wall ins (75mm)	– dbl glazing (post 2003)
		Electric	F (29)	G (13)	D (64)	E (42)	C (74)	D (56)	C (75)	D (59)	– dbl glazing (pre 2003) – St. heating, controls & HWT – CFLs	– Loft ins. (250mm) – Ext. wall ins (75mm)	– dbl glazing (post 2003)

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
HTT: No Fines concrete flat	8: Top floor, gable end (default u-values)	Gas	F (34)	F (32)	E (52)	E (48)	C (76)	C (78)	C (77)	C (80)	– dbl glazing (pre 2003) – Loft ins. (100mm) – CFLs	– loft ins. (250mm) – Boiler/ controls – Ext. wall ins (default)	– dbl glazing (post 2003)
		Electric	F (25)	G (9)	D (59)	F (36)	C (74)	D (57)	C (76)	D (60)	– dbl glazing (pre 2003) – St. heating, controls & HWT – CFLs	– Loft ins. (250mm) – Ext. wall ins (default)	– dbl glazing (post 2003)
HTT: Swedish timber house	9: Semi-detached (user defined u-values)	Gas	F (37)	F (34)	E (50)	E (45)	C (73)	C (73)	B (82)	B (82)	– dbl glazing (pre 2003) – loft ins. (100mm) – CFLs	– loft ins. (250mm) – Boiler/ controls – Ext. or int. wall ins.	– dbl glazing (post 2003) – floor ins – PV
		Electric	F (29)	G (13)	D (59)	F (36)	C (70)	E (50)	C (79)	D (60)	– dbl glazing (post 2003) – Loft ins. (250mm) – St. heating, controls & HWT – CFLs	– Ext. or int. wall ins.	– floor ins – PV

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
HTT: Swedish timber house	9: Semi-detached (default u-values)	Gas	F (32)	F (30)	E (43)	E (39)	C (71)	C (70)	C (79)	C (78)	– dbl glazing (pre 2003) – loft ins. (100mm) – CFLs	– loft ins. (250mm) – Boiler/ controls – Ext. or int. wall ins.	– dbl glazing (post 2003) – floor ins – PV
		Electric	F (22)	G (7)	E (52)	F (28)	D (66)	E (44)	C (73)	E (51)	– dbl glazing (post 2003) – Loft ins. (250mm) – St. heating, controls & HWT – CFLs	– Ext. or int. wall ins. –	– floor ins – PV
HTT: 1950-1982 timber house	10: Semi-detached	Gas	E (45)	E (41)	D (56)	E (51)	C (71)	C (71)	C (79)	C (78)	– dbl glazing (pre 2003) – loft ins. (100mm) – CFLs	– loft ins. (250mm) – Boiler/ controls	– dbl glazing (post 2003) – floor ins – PV
		Electric	E (41)	F (22)	D (66)	E (45)	N/A	N/A	C (74)	E (51)	– dbl glazing (pre 2003) – loft ins. (250mm) – St. heating, controls & HWT – CFLs	– N/A	– floor ins – PV

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
HTT: System-built concrete house	11: Semi-detached	Gas	F (33)	F (31)	D (64)	D (60)	C (75)	C (74)	B (82)	B (82)	– dbl glazing (pre 2003) – boiler/ controls – loft ins. (100mm) – CFLs	– loft ins. (250mm) – ext. wall ins (100mm)	– dbl glazing (post 2003) – floor ins – PV
		Electric	F (23)	G (8)	E (54)	F (30)	C (71)	E (51)	C (78)	D (59)	– dbl glazing (pre 2003) – loft ins. (250mm) – St. heating, controls & HWT – PV – CFLs	– ext. wall ins (100mm)	– floor ins
HTT: BISF steel frame house	12: Semi-detached	Gas	F (33)	F (31)	D (63)	D (60)	C (74)	C (74)	B (81)	B (82)	– dbl glazing (pre 2003) – boiler / controls – loft ins. (100mm) – CFLs	– loft ins. (250mm) – ext. wall ins	– dbl glazing (post 2003) – floor ins – (100mm) – PV

Property type	Sub-archetype	Fuel	Baseline Rating		Post-SHQS Rating		Post-EESSH Rating		Post 2050 Rating		List of Applied Measures		
		Electric	F (23)	G (8)	E (53)	F (30)	C (71)	E (51)	C (78)	D (59)	– dbl glazing (post 2003) – loft ins. (250mm) – St. heating, controls & HWT – PV – CFLs	– ext. wall ins (100mm)	– floor ins

Energy Efficiency Standard for Social Housing: Peer Review

Changeworks & Heriot Watt University

Report Annex: Review and Validation of Consultation Case Studies

Contents

Introduction

The work detailed in this Appendix describes a preliminary review of the case study dwelling specifications, and proposed improvement measures. The work refers to the original „Energy Efficiency Standard for Social Housing" (EESSH) consultation document, for which the RdSAP calculations used a previous version of the methodology (2005 v9.83). This means that where this review refers to the SAP rating or EI rating, these may now be different subject to the revised RdSAP calculations using the more methodology (2009 v9.90 or 9.91).

This case study review uses a suffix of an „E" or a „G" to clarify whether the discussions relate to just an „electric" heated dwelling (for example, case study „1E") or a „gas" heated dwelling (for example, case study „1G"). Absence of these letters implies that the discussion relates to both dwelling types, regardless of the fuel used for heating.

Case Study Group A:

1. **Pre 1919 solid wall ground floor flat, 55m^2**
2. **Pre 1919 solid wall mid floor flat, 58m^2**
3. **Pre 1919 solid wall top floor flat, 67m^2**

Case Study Group A: 1990 Baseline

Walls

- Currently only 2% of the 7.9 million solid wall properties in Great Britain have any form of insulation[1].
- Only 40 of the 487 social rented, pre-1919, solid wall tenement dwellings, surveyed for the 1991 SHCS, had insulation on all external walls. „No insulation" is therefore considered an appropriate assumption for the 1990 baseline.
- The RdSAP methodology v9.91 assumes U-values between 1.6–2.1 W/m^2.K for uninsulated solid walls constructed pre-1919 in Scotland. The range for v9.90 is 1.5-2.1 W/m^2.K, therefore some dwellings may experience slightly greater fabric heat loss under the latest version.

Ground Floor

- Where it is not possible to determine the level of floor insulation, RdSAP assumes „suspended timber floor construction, with no insulation", for pre-1919 Scottish dwellings.

Roof

- Based on observations from the 1991 SHCS, the majority of pre-1919, top-floor tenements from the social housing stock featured a satisfactory level of loft insulation, defined then as 100mm (13.3% of the dwellings where it could be accommodated by 16.8%). This has required further investigation to determine the validity of the baseline assumption, as discussed in Appendix E of the main report of the main report.

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[1] „Estimates of Home Insulation Levels in Great Britain: July 2012", DECC, September 2012

Glazing

- The properties surveyed for the 1991 SHCS indicate that the majority of social rented, pre-1919 tenements featured single glazing, as per the baseline assumption. Only 20% were noted to have fully upgraded to double glazing.

Ventilation: Chimneys

- Almost three quarters of the social rented, pre-1919 tenements, surveyed for the 1991 SHCS, featured a gas or solid fuel fire, and would require some method of ventilation to remove the combustion products. Chimneys should therefore be accounted for within the RdSAP calculation (unless any of the exceptions detailed in section „S4 Parameters for ventilation rate" of Appendix S apply). Exclusion of these will underestimate the level of infiltration associated with the property, and consequently will calculate a reduced space heating requirement.

Space and water heating

- Almost half (48.9%) of the pre 1919, social rented tenements surveyed for the 1991 SHCS did not have central heating. Regardless of this, the RdSAP methodology operates on the basis that the entire dwelling is heated. It should be remembered that the calculated RdSAP data is not representative of actual energy consumption and CO_2 emissions.
- Case study group A specifies 25mm factory applied foam insulation for the hot water cylinder. This is better than the default performance specification (12mm loose jacket) assumed by RdSAP for hot water cylinders in pre 1919 Scottish dwellings. It is not until 1984 that 25mm factory applied foam insulation is the default RdSAP assumption.

Electric heated dwellings

Space and water heating

- Based on observations from the 1991 SHCS, 93% of pre-1919, electric heated, social rented tenements featured storage heaters, and 86% were provided with hot water via electric immersion. This is in line with the 1990 baseline assumptions.

Gas heated dwellings

Space and water heating

- Over a third (35.9%) of the pre-1919, social rented tenement dwellings, surveyed for the 1991 SHCS, featured a gas fuelled heating system.
- It is unlikely that data will be available describing the efficiency of the boiler installed in the 1990 property, therefore it will be necessary to refer to the assumptions detailed within the SAP methodology: Appendix S assumes pre-1998 gas boilers are not fan-assisted, which corresponds to an efficiency of 66% (with the exception of a regular floor mounted boiler installed pre 1979 with an assumed efficiency of 56%).
- Should any of the efficiency adjustments outlined in Table 4c of the SAP methodology be applicable, the boiler efficiency may be reduced by 5%. This means a regular, non-condensing, pre-1998 gas boiler (not fan assisted) without any thermostatic control of room temperature is assumed to have a winter efficiency of 61%.

Recommendations:

- The remaining number of open chimneys and/or flues should be considered for pre-1919 dwellings.
- The minimum efficiency assumed for the winter boiler efficiency (applied for the space heating requirement) should be no less than 61%.

Case Study Group A: SHQS 2015 Assumptions

- Element 31 of Annex C is not applicable to case study group A, where the dwellings cannot accommodate cavity wall insulation.
- Element 32 of Annex C is not applicable to case study 1 or 2 of group A, where they cannot accommodate loft insulation.
- The case studies detail 25mm of factory applied foam insulation on the hot water tanks. As long as the pipes are insulated, or contribute to the space heating requirement, case study group A complies with element 33 of Annex C.
- Sub-elements 34A and 34B require the dwellings to feature a full central heating system (addressing all habitable rooms, excluding the kitchen and bathroom), and that it be deemed efficient. Both the storage heaters and gas boilers specified for the baseline dwellings meet the necessary criteria.
- Element 35 of Annex C potentially creates the greatest challenge for case study group A, where it specifies a minimum NHER or SAP rating. Solid wall dwellings are „hard to treat", therefore likely to require additional energy efficiency measures beyond the minimum standards prescribed by elements 31 to 34 of Annex C. These are discussed under the headings for electric and gas fuel sources.

Roof

- Loft insulation (of minimum 100mm thickness) must be installed for case study 3, in line with element 32 of the SHQS 2015 criteria.

Electric heated dwellings

Space and water heating

- Free-standing, large volume, electric storage systems may be deemed efficient if installed after 1984, however it may be necessary to upgrade to an improved system to help exceed the minimum SAP rating for element 35 of Annex C.
- The proposed fan storage heater will have the same efficiency, but will benefit from increased „responsiveness"[2] and automatic controls. This will contribute to reduced space heating requirements, fuel costs and consequently a better SAP rating.
- The improvement to the hot water tank insulation, increasing the factory applied foam insulation thickness from 25mm to 80mm, identifies an additional method by which landlords can help improve the dwellings SAP rating for element 35.

[2] „Table 4a: Heating Systems (space and water)", SAP 2009 v9.90

Glazing

- Case study 1E is reliant on the installation of double glazing to help achieve the minimum SAP rating. Specification of pre-2003 glazing allows landlords to view the potential benefits associated with this measure, whilst providing flexibility to choose better glazing specifications to realise the SAP rating should they not be able to accommodate any of the other proposed energy efficiency measures.
- Case study 2E specifies the installation of double glazing. Application of all the „SHQS 2015" improvements demonstrates a SAP rating of 67, which is 9 points above the minimum criteria for element 35 of Annex C.
- Many older dwellings experience difficulties accommodating improvement measures such as replacement glazing, where they are subject to listed building status or considered to be of historical interest. Such instances will require correspondence with the local planning authority and consideration of any additional costs that may be incurred.

Gas heated dwellings

- The 1990 baselines for case study 1G and 2G meet all the criteria for „SHQS 2015": cavity and loft insulation are not applicable, the properties feature a full central heating system with an efficiency greater than 55%, and the SAP rating is better than the minimum specification.
- These case studies demonstrate that „hard to treat" properties can still comply with the SHQS 2015 criteria, without relying on measures which can be restricted in their application due to factors such as listed building status.
- The 1990 baseline of case study 3G is reliant on further improvement measures to meet elements 32 and 35 of Annex C, which include 100mm of loft insulation and improved glazing.

Glazing

- Despite meeting compliance, the „SHQS 2015" stage still consider the benefits of installing pre-2003 double glazing for the gas heated case study group A. This allows landlords to view the potential benefit of this measure.
- It should be noted that whilst the properties feature a 61% efficient boiler, the magnitude of the fuel bill and CO_2 *savings*, subject to the installation of double glazing, will appear greater compared to the application of this measure in a dwelling featuring a more efficient boiler. The *overall* fuel bills and CO_2 emissions will be lower for the property with the more efficient boiler.

Recommendations:

- Additional case studies should identify strategies to meet compliance for hard to treat buildings, which may be subject to listed building status and therefore unable to accommodate typical measures such as improved glazing.

Case Study Group A: Further measures 2020

- The EESSH outlines a minimum EI rating to be achieved, which for an electric and gas heated dwelling are:
  - E (50) and D (65) respectively for a ground floor flat,
  - C (70) and C (80) respectively for a mid- floor flat, and
  - D (60) and C (70) respectively for a top floor flat.
- Case study 1E and 2E do not consider any additional efficiency measures under the „Further Measures 2020" stage, even though they fall short of meeting the minimum EI rating.
- A number of additional measures are specified for case study 2G, however these are not successful in exceeding the minimum EI rating.
- A number of additional measures are specified for case studies 1G, 3E and 3G which are successful in exceeding the minimum EI ratings.

Roof

- The loft insulation is increased to a thickness of 250mm for both electric and gas heated dwellings (only applicable to case study 3). Combined with the other specified improvements, the electric heated case study just exceeds the minimum EI rating, whereas the gas heated case study is 9 points above the minimum criteria.

Electric heated dwellings

Glazing

- In addition to increased loft insulation, case study 3E specifies post-2003 glazing as an improvement measure under the „Further Measures 2020" stage.
- The specification of post-2003 glazing appears critical to meeting the EESSH criteria, where the case study only just exceeds the minimum EI rating.
- The installation of post-2003 glazing specification may be limited in its application due to factors such as listed building status, or the prior upgrade of double glazing to pre-2003 standard. If this is the case, social landlords may need to identify alternative technologies to help reduce the building"s energy consumption.

Gas heated dwellings

Space and water heating

- The indicative life expectancy for a condensing boiler is in the region of 15 years[3], therefore installation of a new system is appropriate for both the „SHQS 2015" or „Further Measures 2020" improvement stages. This also provides an opportunity to upgrade the control strategy.
- Table 4b of the SAP methodology specifies a non-condensing combi-boiler to have an efficiency of 70-74%. Any installations after 2005 are likely to be condensing systems, thus assume an efficiency of 80-84%. The case study control specification indicates that the system does not qualify for any efficiency adjustments detailed in table 4c of the SAP methodology.

[3] „Indicative life expectancy for building services plant, equipment and systems", http://www.cibse.org/pdfs/newOOMtable1.pdf

- An improved boiler efficiency will yield considerable space heating and hot water energy reductions. Standard 6.3 of the Domestic Technical Handbook specifies a minimum seasonal efficiency of 88% (SEDBUK 2009) for gas boilers. It is proposed that this value is used to describe the efficiency for any future installations, where it represents the current minimum standards.
- A more efficient boiler will use less energy to address the load on the heating system. Any *savings* realised by a measure which reduces the load on the heating system will be greater under the operation of a less efficient boiler, compared to a more efficient system. This is important to bear in mind when considering the cumulative effect of implementing energy efficiency measures over a number of stages: the benefits of individual measures cannot be added together.

Recommendations:

- Additional efficiency measures should be considered under the „Further Measures 2020" stage to ensure case studies 1E, 2E and 2G meet the minimum EI ratings for their corresponding dwelling type.
- Consideration should be given to the potential benefits of other fuel sources and heating systems to realise the proposed targets, particularly for hard to treat dwellings. Should this involve a change of fuel type (e.g. from electric to gas where feasible), consideration must be given to the efficiency and carbon intensity associated with the new system, to ensure an overall reduction in CO_2 emissions[4].
- An assumed gas boiler efficiency of 88% is proposed, in line with the minimum standards outlined by Standard 6.3 of the Domestic Technical Handbook.
- Social landlords should be reminded that the case studies demonstrate the cumulative application of efficiency measures over three stages, and the potential benefits realised by a single measure are subject to changes relative to the other measures in place.
- Additional case studies should identify strategies to meet compliance for hard to treat buildings, which may be subject to listing building status and therefore unable to accommodate typical measures such as improved glazing.

Case Study Group A: Advanced measures 2050

Walls

- Solid wall properties are identified as „hard to treat" (HTT) therefore it is unlikely that insulation of the external walls will be a measure considered prior to the „Advanced Measures 2050" stage.
- Within Scotland many of the older domestic properties are listed, which may prohibit the application of external insulation. Further complications may also be introduced in trying to address a mixed tenure block. Whilst internal insulation may be considered a more appropriate approach in such instances,

[4] Section 1.7 Replacement of Primary Heating Appliances, Domestic Building Services Compliance Guide, HM Government, 2010 Edition with 2011 Amendments.

there are again limitations in its application, whether due to the reduction in internal floor area or incompatibility with internal features.

Floors

- The RdSAP calculation used to determine the U-value for a suspended timber floor does not appear to accommodate insulation within the equation. This means that social landlords may wish to provide documented evidence of the improved floor U-value, if they wish to override the default values used in the calculation.
- The installation of floor insulation is a particularly disruptive process, and would likely incur additional expense (where occupants may require alternative accommodation and storage of their possessions for the duration of the work). The installation of other improvement measures which require the floorboards to be raised, such as the installation of a central heating system, may provide an opportunity to install floor insulation with minimal additional disruption.
- The process of insulating suspended timber floors requires careful consideration, in terms of damage limitation when lifting floorboards, and ensuring a sufficient level of cross ventilation is maintained to mitigate the development of damp or rot.

Glazing

- It is useful to demonstrate the benefits associated with further improved glazing to post-2003 standards, where this is a feasible measure (for case studies 1, 2, and gas heated case study 3G). Considered alongside other technologies under the „Advanced Measures 2050" stage of improvements, it is difficult to identify the glazing contribution towards the reduction in energy consumption and CO_2 emissions, however it is unlikely it will be a measure undertaken earlier in the process where the glazing was previously assumed to have been upgraded for the „SHQS 2015" stage.

Recommendations:

- Social landlords should be advised to acquire documented evidence detailing the U-value associated with an insulated suspended timber floor should they wish to override the default assumptions used in the RdSAP calculations.

Case Study Group B

4. **Interwar cavity wall mid floor flat, 78m^2**
5. **Interwar cavity wall mid terrace house, 80m^2**
6. **Interwar cavity wall semi-detached house, 92m^2**

Case Study Group B: 1990 Baseline

Walls

- 492 social rented tenement dwellings, identified by the 1991 SHCS, were constructed between 1919 and 1944:
  - Only 15% featured any form of wall insulation to all external walls.
- 363 mid-terrace, end-terrace and semi-detached dwellings were identified by the 1991 SHCS as belonging to the social housing sector and constructed between 1919 and 1944:
  - Of the 92 mid-terrace dwellings, only 39% were noted to have some form of insulation to all external walls.
  - Of the 271 semi-detached or end-terrace dwellings, only 34% were noted to have some form of insulation to all external walls.
- Based on the above, „no insulation" is considered an appropriate assumption for the 1990 baseline case studies.
- The RdSAP methodology assumes the same performance parameters for age bands B (1919-1929) and C (1930-1949) with respect to wall thickness and U-values. For a cavity wall (as built) in Scotland, this is a thickness of 300mm and U-value of 1.6 W/m^2.K (v9.90 and v9.91).

Floor

- Where it is not possible to determine the level of floor insulation, the RdSAP methodology assumes a solid floor with no insulation for Scottish dwellings constructed between 1930 and 1991 (RdSAP age bands C to G).
- Based on the calculation detailed in section S5.4 of Appendix S, the U-value calculated for case studies 5 and 6 is in the region of 0.52 W/m^2.K and 0.64 W/m^2.K respectively.

Roof

- The majority of 1919-1944 social rented houses (mid-terrace, end-terrace and semi-detached only), surveyed for the 1991 SHCS, featured a satisfactorily level of loft insulation (81%), defined then as 100mm. This has required further investigation to determine the validity of the baseline assumption, as discussed in Appendix E of the main report.

Glazing

- The properties surveyed for the 1991 SHCS indicate that:
  - the majority of social rented tenements, constructed between 1919 and 1944, featured single glazing (70%), as per the baseline assumption. 27% were noted to have fully upgraded to double glazing.
  - the majority of social rented, houses constructed between 1919 and 1949 featured single glazing (71%), as per the baseline assumption. 26% were noted to have fully upgraded to double glazing.

Ventilation: Chimneys

- Over three quarters (78%) of the social rented tenements, constructed between 1919 and 1944 and surveyed for the 1991 SHCS, featured a gas or solid fuel fire.
- The 1991 SHCS indicates that 87% of social rented houses (mid-terrace, end-terrace and semi-detached only) constructed between 1919 and 1944, featured a gas or solid fuel fire.
- These dwellings would likely require some form of open chimney to remove combustion products and this should be accounted for within the RdSAP calculation (unless any of the exceptions detailed in section „S4 Parameters for ventilation rate" of Appendix S apply). Exclusion of this will contribute to an underestimation of the infiltration associated with the dwellings, and consequently a reduced space heating requirement.

Space and water heating

- 60% of social rented tenements and 40% of the social rented houses (mid-terrace, end-terrace and semi-detached only), constructed between 1919 and 1944 and surveyed for the 1991 SHCS, only had partial or no central heating. Despite this, the RdSAP methodology operates on the basis that the entire dwelling is heated. It should be remembered that the calculated values are not representative of actual energy consumption and CO_2 emissions.
- Case study group B specifies a factory applied foam insulation thickness of 25mm for the hot water cylinder. This is better than the default performance specification (12mm loose jacket) assumed by RdSAP for hot water cylinders in Scottish dwellings constructed between 1919 and 1949. It is not until 1984 that 25mm factory applied foam insulation is the default RdSAP assumption.

Electric heated dwellings

Space and water heating

- Based on observations from the 1991 SHCS,
    - 82% of electric heated, social rented tenement dwellings constructed between 1919 and 1944, featured storage heaters and 92% used electric immersion to provide hot water.
    - 98% of electric heated, social rented houses, constructed between 1919 and 1944, featured storage heaters, and 76% were provided with hot water via electric immersion
- The 1990 baseline assumptions are in line with these observations.

Gas heated dwellings

Space and water heating

- It is unlikely that data will be available describing the efficiency of the boiler installed in the 1990 property, therefore it will be necessary to refer to the assumptions detailed within the SAP methodology: Appendix S assumes pre 1998 gas boilers are not fan-assisted, which corresponds to an efficiency of 66% (with the exception of a regular floor mounted boiler installed pre 1979 with an assumed efficiency of 56%).
- Should any of the efficiency adjustments outlined in Table 4c of the SAP methodology be applicable, the boiler efficiency may be reduced by 5%. This means a regular, non-condensing, pre-1998 gas boiler (not fan assisted), without any thermostatic control of room temperature, will be assumed to have an overall efficiency of 61%.

Recommendations:

- Social landlords should be advised to obtain documentary evidence of the improved U-value for insulated suspended timber flooring, if they wish to override the default assumption used in RdSAP.
- Reference should be made to Appendix E of the main report regarding the loft insulation assumptions for the 1990 baseline dwelling.
- A count of the chimneys and/or flues should be included for dwellings constructed between 1919 and 1949.
- The minimum efficiency assumed for the boiler winter seasonal efficiency (applied for the space heating requirement) should not be less than 61%.

Case Study Group B: SHQS 2015

- The case studies feature 25mm of factory applied foam insulation to the hot water tank. As long as the pipes are insulated, or contribute to the space heating requirement, case study group B will comply with element 33 of Annex C.
- Sub-elements 34A and 34B require that the property features a full central heating system addressing all habitable rooms (excluding the kitchen and bathroom), and that it is deemed efficient. Both the storage heaters and gas boiler specified for the 1990 baselines meet the necessary criteria.
- The 1990 baseline version of the gas heated case study 4G exceeds the minimum SAP rating to meet compliance with Element 35 of Annex C, however improvement measures are required to meet compliance with the other elements of Annex C.

Walls

- Based on element 31 of Annex C for the SHQS cavity wall insulation must be installed for all the dwellings in case study group B.
- The RdSAP assumptions specify a U-value of 0.50 $W/m^2.K$ for a filled cavity wall constructed in Scotland between 1919 and 1949. This performance specification is better than the default assumptions associated with insulated timber frame constructions (0.55 $W/m^2.K$) or system build (0.60 $W/m^2.K$) therefore these latter construction types are likely to experience greater challenges to realising the necessary SHQS SAP rating.

Roof

- Loft insulation of at least 100mm thickness is necessary to meet compliance with element 32 of Annex C for the SHQS (this is not applicable to case study 4 which cannot accommodate loft insulation).

Electric heated dwellings

Roof

- Electric heated case studies 5E and 6E must increase the loft insulation thickness to 250mm, to exceed the minimum SAP rating, in line with element 35 of Annex C.

Glazing

- Case study 4E specifies the installation of pre-2003 double glazing. This measure, in addition to the wall insulation, helps achieve a SAP rating of 69, which is 11 points above the minimum criteria for element 35 of Annex C.

- Case study 5E also specifies the installation of pre-2003 double glazing, whereas the specification of post-2003 glazing for case study 6E emphasises the challenge this dwelling faces in trying to meet compliance with element 35 of Annex C.

  Space and water heating
- The fan storage heaters specified for case studies 5E and 6E will have the same efficiency as the previous system, but will benefit from increased „responsiveness"[5] and automatic controls. This will contribute to reduced space heating requirements, fuel costs and consequently a better SAP rating.
- The improvement to the hot water tank insulation for case studies 5E and 6E, increasing the factory applied foam insulation thickness from 25mm to 80mm, identifies additional efforts landlords can implement to help realise the necessary SAP rating for element 35

Gas heated dwellings

Roof
- Gas heated case studies 5G and 6G meet compliance with the SHQS 2015 criteria by specifying the minimum loft insulation thickness of 100mm.

  Glazing
- In addition to the cavity wall and loft insulation, case study 6G specifies pre-2003 glazing as an improvement measure under the „SHQS 2015" stage. The combined installation of these measures takes the SAP rating well above the minimum requirement.

Recommendations:
- There are no recommended changes to the assumptions specified for the „SHQS 2015" improvement stage, for case study group B.

Case Study Group B: Further measures 2020

- The EESSH outlines a minimum EI rating to be achieved for electric and gas heated dwellings, which are:
  - C (70) and C (80) respectively for a mid- floor flat,
  - D (55) and C (70) respectively for a mid-terrace house, and
  - E (50) and D (65) respectively for an end-terrace/semi-detached house.
- Case study 4E just meets the minimum EI rating subject to the previous improvements undertaken for the „SHQS 2015" stage, but further improvements are still considered.
- Electric heated case studies 5E and 6E do not consider any further improvements for this stage, where they have already met the EESSH criteria subject to the SHQS 2015 improvement measures.
- Gas heated case studies 4G, 5G and 6G require further measures to exceed the aforementioned EI ratings.

[5] „ Table 4a: Heating Systems (space and water)", SAP 2009 v9.90

Electric heated dwellings

Space and water heating

- The fan storage heater specified for case study 4E will have the same efficiency as the older storage system, but will benefit from increased „responsiveness"[6] and automatic controls. This will contribute to reduced space heating requirements, and consequently an improved EI rating.
- The improvement to the hot water tank insulation for case study 4E, increasing the factory applied foam insulation thickness from 25mm to 80mm, identifies another method by which landlords can reduce the hot water energy consumption, CO_2 emissions and consequently EI rating.

Gas heated dwellings

Roof

- It has been necessary to increase the loft insulation thickness to 250mm for case studies 5G and 6G (in addition to upgrading the heating system) to exceed the proposed EI rating in line with the EESSH.

Glazing

- The specification of post-2003 glazing for case study 4G (in addition to an upgraded heating system) assists in exceeding the target EI rating by 5 points.

Space and water heating

- The indicative life expectancy for a condensing boiler is in the region of 15 years[7], therefore installation of a new system is appropriate for both the „SHQS 2015" or „Further Measures 2020" improvement stages. This also provides an opportunity to upgrade the control strategy.
- Table 4b of the SAP methodology specifies a non-condensing combi-boiler to have an efficiency of 70-74%. Any installations after 2005 will be condensing systems, thus assume an efficiency of 80-84%. The case study control specification indicates that the system does not qualify for any efficiency adjustments detailed in table 4c of the SAP methodology.
- An improved boiler efficiency will yield considerable space heating and hot water energy reductions. Standard 6.3 of the Domestic Technical Handbook specifies a minimum seasonal efficiency of 88% (SEDBUK 2009) for gas boilers. It is proposed that this value is used to describe the efficiency for any future installations, where it represents the current minimum standards.

Recommendations:

- An assumed gas boiler efficiency of 88% is proposed in line with the minimum standards outlined by Standard 6.3 of the Domestic Technical Handbook.
- Social landlords should be reminded that the case studies demonstrate the cumulative application of efficiency measures over three stages, and the potential benefits realised by a single measure are subject to change in relation to the other measures in place.

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[6] „ Table 4a: Heating Systems (space and water)", SAP 2009 v9.90

[7] „Indicative life expectancy for building services plant, equipment and systems", http://www.cibse.org/pdfs/newOOMtable1.pdf

Case Study Group B: Advanced measures 2050

Floor

- The installation of floor insulation (applicable to case studies 5 and 6) is a particularly disruptive process. It would likely incur additional expense for the duration of the work, where occupants may need to be provided with alternative accommodation and their possessions put into storage. Despite this, the installation of other improvement measures which require the floorboards to be raised (such as installation of a central heating system) may provide an opportunity to install the floor insulation with minimal additional disruption.
- The default performance parameters associated with the floor construction are one of the only factors which differentiate dwellings from RdSAP age band B and RdSAP age band C, where the former assumes suspended timber and the latter solid floors.
- The installation of 50mm of floor insulation improves the U-value of a solid ground floor from 0.52 $W/m^2.k$ to 0.28 $W/m^2.K$ (for case study 5) and 0.64 $W/m^2.k$ to 0.32 $W/m^2.K$ (for case study 6).
- The calculation provided by the RdSAP methodology to determine the U-value for suspended timber floors does not appear to accommodate the benefit of insulation. Social landlords may wish to provide documentary evidence of the improved floor U-value, should they wish to override the default assumption applied for the RdSAP calculation.

Renewables: Solar PVs to 20% of roof

- Photovoltaic technology (specified for case studies 5 and 6) will only be suitable for a limited number of properties, where they meet sufficient criteria to ensure the effective operation of the technology (e.g. suitable orientation, sufficient space on the roof, optimal angle of roof, minimal over shading).
- Should optimal conditions associated with any of the above criteria not be met, additional costs may be incurred to optimise operational conditions (e.g. investment in a supporting frame to improve the tilt angle, or multiple inverters to minimise the impact of shading for periods of the day).

Electric heated dwellings

Glazing

- Considered independent of other measures, the RdSAP calculation indicates a further 5% reduction in CO_2 emissions associated with the specification of post-2003 glazing (replacing pre-2003 glazing), for electric heated case study 4E.

Gas Heating

Glazing

- Post-2003 double glazing is included as an „Advanced Measure 2050" for gas heated case studies 5G and 6G. It is unlikely that this measure will be implemented in the near future subject to the prior installation „pre-2003" glazing.

Recommendations:

- Social landlords should be advised to acquire documented evidence detailing the U-value associated with an insulated suspended timber floor, should they wish to override the default assumptions used in the RdSAP calculations.

Case Study Group C

7. **1919-1949 Four in a block, Lower, 94m^2**
8. **1919-1949 Four in a block, Upper, 87m^2**

Case Study Group C: 1990 Baseline

Walls

- 742 four in a block dwellings were identified by the 1991 SHCS as belonging to the social housing sector, and constructed between 1919 and 1944. Of these, 90% featured cavity wall construction.
- The 1990 baseline assumption of „no insulation‟ is in line with the majority of these dwellings, where only 24% of the 742 dwellings were noted to have some form of insulation to all external walls.
- The RdSAP methodology v9.91 assumes a wall U-value of 1.6 W/m^2.K for age bands B & C cavity walls (as built) in Scotland (v9.90 and v9.91).

Ground Floor

- Where it is not possible to determine the level of floor insulation, the RdSAP methodology assumes a solid floor with no insulation for Scottish dwellings constructed between 1930 and 1991 (RdSAP age bands C to G).
- Based on the calculation detailed in section S5.4 of Appendix S, a U-value of 0.53 W/m^2.K is determined for case study 7.

Roof

- Observations from the 1991 SHCS indicate that the majority (77%) of social rented, four in a block dwellings, constructed between 1919-1944 and able to accommodate loft insulation, featured a satisfactorily level (defined then as 100mm). This has required further investigation to determine the validity of the baseline assumption, as discussed in Appendix E of the main report.

Glazing

- The majority (74%) of the 742 social rented, four in a block dwellings (identified by the 1991 SHCS) featured single glazing, although a quarter were observed to have fully upgraded to double glazing.

Ventilation: Chimneys

- The 1991 SHCS indicates that 87% of social rented, four in a block dwellings, constructed between 1919 and 1944, featured a gas or solid fuel fire.
- These would require some form of open chimney to remove combustion products. The RdSAP calculation should include a count of chimney or flues (unless it meets any of the criteria specified in section „S4 Parameters for ventilation rate‟ of Appendix S). Exclusion of this will contribute to an underestimation of the infiltration associated with the property and consequently a reduced space heating requirement.

Space and water heating

- The 1991 SHCS indicates that just over a fifth (22%) of the social rented, four in a block dwellings, constructed between 1919 and 1944, do not feature any central heating and 24% had only partial central heating. Despite this, the RdSAP calculation operates under the assumption that the entire dwelling is heated. It should be remembered that the calculated values are not representative of actual energy consumption and CO_2 emissions.

- Case studies 7E and 7G specify 25mm of factory applied foam insulation for the hot water cylinder. This is better than the default performance specification (12mm loose jacket) assumed by RdSAP for hot water cylinders in 1919-1944 Scottish dwellings. It is not until after 1984 that 25mm factory applied foam insulation is the default RdSAP assumption

Electric heated dwellings

Space and water heating

- Based on observations from the 1991 SHCS, 91% of electric heated, social rented four in a block dwellings, constructed between 1919 and 1944, featured storage heaters, and 84% were provided with hot water via electric immersion.
- The 1990 baseline assumptions reflect these observations.

Gas heating and hot water

Space and water heating

- It is unlikely that data will be available describing the efficiency of the boiler installed in the 1990 property, therefore it will be necessary to refer to the assumptions detailed within the SAP methodology: Appendix S assumes pre 1998 gas boilers are not fan-assisted, which corresponds to an efficiency of 66% (with the exception of a regular floor mounted boiler installed pre 1979 with an assumed efficiency of 56%).
- Should any of the efficiency adjustments outlined in Table 4c of the SAP methodology be applicable, the boiler efficiency may be reduced by 5%. This means a regular, non-condensing, pre-1998 gas boiler (not fan assisted) without any thermostatic control of room temperature will be assumed to have an overall efficiency of 61%.

Recommendations:

- The remaining number of open chimneys and/or flues should be considered for dwellings constructed between 1919 and 1949.
- The minimum efficiency assumed for the boiler winter seasonal efficiency (applied for the space heating requirement) should be no less than 61%.

Case Study Group C: SHQS 2015

- The case studies feature 25mm of factory applied foam insulation on the hot water tank. As long as the pipes are insulated, or contribute to the space heating requirement, case study group C complies with element 33 of Annex C.
- Sub-elements 34A and 34B require that the property features a full central heating system addressing all habitable rooms (excluding the kitchen and bathroom), and that it is deemed efficient. Both the storage heaters and gas boilers specified for the baseline property meet the necessary criteria.

Walls

- Based on element 31 of Annex C, for the SHQS, cavity wall insulation must be installed.

- The RdSAP assumptions specify a U-value of 0.50 W/m^2.K for a filled cavity wall constructed in Scotland between 1919 and1949. This performance specification is better than the default assumptions associated with v9.90 insulated timber frame constructions (0.55 W/m^2.K) or system build (0.60 W/m^2.K) therefore such construction types are likely to experience greater challenges to realising the necessary SHQS SAP rating.

Roof

- Loft insulation of at least 100mm thickness is necessary to meet compliance with element 32 of Annex C for the SHQS.
- This is only applicable to case study 8 (where it cannot be accommodated by case study 7).

Electric heated dwellings

Roof

- To exceed the minimum SAP rating, it is necessary to increase the loft insulation thickness from the minimum 100mm, to 250mm for case study 8E.

Glazing

- The selection of post-2003 glazing over pre-2003 glazing emphasises the challenge faced by case study 7E to comply with element 35 of Annex C. This means this measure, in association with the other proposed improvements, helps the dwelling exceed the minimum SAP rating by just four points.
- Case study 8E is reliant on the installation of double glazing to help achieve the minimum SAP rating. Specification of pre-2003 glazing allows landlords to view the potential benefits associated with this measure, whilst providing flexibility to choose better glazing specifications to realise the SAP rating should they not be able to accommodate any of the other energy efficiency measures outlined.

Space and water heating

- The fan storage heaters, specified for case study 7E, will have the same efficiency as the older storage systems, but will benefit from increased „responsiveness‟[8] and automatic controls. This will contribute to a reduction in the space heating requirement, and consequently an improved SAP rating.
- The increased hot water tank insulation, specified for case study 7E, identifies another method by which landlords can reduce the hot water energy consumption, CO_2 emissions and consequently SAP rating.

Gas heated dwellings

Roof

- Case study 8G meets compliance with element 32 by specifying the minimum 100mm of loft insulation.

Recommendations:

- There are no recommended changes to the assumptions specified for the „SHQS 2015‟ improvement stage, for case study group C.

[8] „Table 4a: Heating Systems (space and water)‟

Case Study Group C: Further measures 2020

- The EESSH outlines a minimum EI rating to be achieved for electric fuelled properties and gas fuelled properties, which are:
    - E (50) and D (60) respectively for a lower four in a block dwelling, and
    - D (55) and D (60) respectively for an upper four in a block dwelling.
- The additional energy efficiency measures necessary to qualify for the SHQS 2015 SAP rating mean electric heated case studies 7E and 8E already meet the required rating. Case study 8E still goes on to consider the effect of upgrading the heating system under the „further measures 2020" stage of improvements.
- Gas heated case studies 7G and 8G require further measures to exceed the aforementioned EI rating.

Electric space and water heating

Space and water heating

- The fan storage heaters considered for case study 8E will have the same efficiency as the older storage systems, but will benefit from increased „responsiveness"[9] and automatic controls. This will contribute to a reduction in the space heating requirement, and consequently an improved EI rating.
- The improved hot water tank insulation specified for case study 8E (increasing the factory applied foam insulation from 25mm to 80mm) identifies another method by which landlords can reduce the hot water energy consumption, CO_2 emissions and consequently EI rating.

Gas heating and hot-water

Roof

- In order to exceed the proposed EI rating in line with the EESSH, the loft insulation thickness for case study 8G has been increased to 250mm in addition to upgrading the heating system. The combined effect of these measures takes the EI rating well above the minimum value, by as much as 16 points.

Space and water heating

- The indicative life expectancy for a condensing boiler is in the region of 15 years[10], therefore installation of a new system is appropriate for both the „SHQS 2015" or „Further Measures 2020" improvement stages. This also provides an opportunity to upgrade the control strategy.
- Table 4b of the SAP methodology specifies a non-condensing combi-boiler to have an efficiency of 70-74%. Any installations after 2005 will be condensing systems, thus assume an efficiency of 80-84%. The case study control specification indicates that the system does not qualify for any efficiency adjustments detailed in table 4c of the SAP methodology.
- An improved boiler efficiency will yield considerable space heating and hot water energy reductions. Standard 6.3 of the Domestic Technical Handbook specifies a minimum seasonal efficiency of 88% (SEDBUK 2009) for gas

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[9] „ Table 4a: Heating Systems (space and water)"

[10] „Indicative life expectancy for building services plant, equipment and systems", http://www.cibse.org/pdfs/newOOMtable1.pdf

boilers. It is proposed that this value is used to describe the efficiency for any future installations, where it represents the current minimum standards.

- A more efficient boiler will use less energy to address the load on the heating system. Any *savings* realised by a measure which reduces the load on the heating system will be greater under the operation of a less efficient boiler compared to a more efficient system. This is important to bear in mind when considering the cumulative effect of implementing energy efficiency measures installed over a number of stages: the benefits of individual measures cannot be added together.

Recommendations:

- An assumed gas boiler efficiency of 88% is proposed in line with the minimum standards outlined by Standard 6.3 of the Domestic Technical Handbook.
- Social landlords should be reminded that the case studies demonstrate the cumulative application of efficiency measures over three stages, and the potential benefits realised by a single measure are subject to change in relation to the other measures in place.

Case Study Group C: Advanced measures 2050

Floor

- The installation of floor insulation is a particularly disruptive process, and would likely incur additional expense for the duration of the work, where occupants may need to be provided with alternative accommodation and their possessions put into storage. Despite this, the installation of other improvement measures which require the floorboards to be raised (such as installation of a central heating system) may provide an opportunity to install the floor insulation with minimal additional disruption.
- The default performance parameters associated with the floor construction are one of the only factors which differentiate dwellings from RdSAP age band B and RdSAP age band C. The former construction period assumes suspended timber floors, and the latter solid floors.
- The installation of 50mm of floor insulation improves the U-value of a solid ground floor (applicable to case study 7 only) from 0.52 W/m^2.k to 0.28 W/m^2.K.
- The calculation provided by the RdSAP methodology to determine the U-value for suspended timber floors does not appear to accommodate the benefit of insulation. Social landlord may wish to provide documentary evidence of the improved floor U-value, should they wish to override the default assumption applied for the RdSAP calculation.

Gas space and water heating

Glazing

- Post 2003 double glazing is included as an „Advanced Measure 2050", where it is unlikely that this measure will be implemented in the near future subject to „pre-2003" glazing being one of the previous improvement efforts.

Recommendations:

- Social landlords should be advised to acquire documented evidence detailing the improved U-value associated with an insulated suspended timber floor, should they wish to override the default RdSAP assumption.

Case Study Group D

9. **1950-1964 mid floor flat, 110m^2**
10. **1950-1964 mid-terrace house, 70m^2**
11. **1950-1964 semi-detached house, 84m^2**

Case Study Group D: 1990 Baseline

Walls

- 957 tenement dwellings were identified by the 1991 SHCS as belonging to the social housing sector and constructed between 1945 and 1964.
  - 89% featured cavity wall construction.
  - 22% were noted to have some form of insulation to all external walls.
- 1395 mid-terrace, end-terrace and semi-detached dwellings were identified by the 1991 SHCS as belonging to the social housing sector and constructed between 1945 and 1964.
  - 504 of these were mid-terrace dwellings, of which 92% featured cavity wall construction.
  - 891 of these were end-terrace or semi-detached dwellings, of which 89% featured cavity wall construction.
  - 41% of the mid-terrace dwellings were noted to have some form of insulation to all external walls.
  - an increasing proportion of end-terrace and semi-detached houses (45%) were noted to have some form of insulation to all external walls.
- The 1990 baseline assumption of „no insulation" is in line with the greater proportion of these dwellings.
- The RdSAP methodology v9.91 assumes a wall U-value of 1.6 W/m^2.K for age band D cavity walls (as built) in Scotland (v9.90 and v9.91).

Ground Floor

- Where it is not possible to determine the level of floor insulation, the RdSAP methodology assumes a solid floor with no insulation for Scottish dwellings constructed between 1930 and 1991 (RdSAP age bands C to G).
- Based on the calculation detailed in section S5.4 of Appendix S, the U-values calculated for case studies 10 and 11 are 0.48 W/m^2.K and 0.74 W/m^2.K respectively.

Roof

- The 1991 SHCS survey indicates that 84% of social rented houses constructed between 1945 and 1964 (mid-terrace, end-terraced and semi-detached only) featured a satisfactory level of loft insulation, defined then as 100mm. This has required further investigation to determine the validity of the baseline assumption, as discussed in Appendix E of the main report.

Glazing

- The majority of the 957 social rented tenement dwellings constructed between 1945 and 1964 (and surveyed for the 1991 SHCS) featured single glazing (82%). 15% were noted to have fully upgraded to double glazing.
- The majority of the 1395 social rented mid-terrace, end-terrace and semi-detached houses constructed between 1945 and 1964 (and surveyed for the

1991 SHCS), featured single glazing (74%), although 21% were noted to have fully upgraded to double glazing.

Ventilation: Chimneys

- The 1991 SHCS indicates that:
    - just over half (55%) of social rented, tenement dwellings constructed between 1945 and 1964, featured a gas or solid fuel fire.
    - 82% of social rented houses (mid-terrace, end-terrace and semi-detached only) constructed between 1945 and 1964, featured a gas or solid fuel fire.
- These properties would likely require some form of open chimney to remove combustion products. The RdSAP calculation should therefore include a count of chimney or flues (unless the dwellings meet any of the criteria specified in section „S4 Parameters for ventilation rate" of Appendix S). Exclusion of this will contribute to an underestimation of the infiltration associated with the property and consequently a reduced space heating requirement.

Space and water heating

- The 1991 SHCS indicates that over half (55%) of the social rented tenements constructed 1945-1964 did not feature any central heating, and 17% had only partial central heating.
- Compared to the previous age groups and building types, a decreasing number of social rented houses (mid-terrace, end-terrace and semi-detached only) constructed between 1945 and 1964 and surveyed for the 1991 SHCS did not feature any central heating (38%).
- The RdSAP calculation operates under the assumption that the entire dwelling is heated. It should be remembered that the calculated values are not representative of actual energy consumption and CO_2 emissions.
- Case study group D specifies factory applied foam insulation thickness of 25mm for the hot water cylinder. This is better than the default performance specification (12mm loose jacket) assumed by RdSAP for hot water cylinders in 1945-1964 constructed Scottish dwellings. It is not until after 1984 that 25mm factory applied foam insulation is the default RdSAP assumption.

Electric heated dwellings

- Based on observations from the 1991 SHCS:
    - 88% of electric heated, social rented tenement dwellings constructed between 1945 and 1964, featured storage heaters and 91% used electric immersion to provide hot water.
    - 92% of electric heated, social rented houses (mid-terrace, end-terrace and semi-detached only), constructed between 1945 and 1964, featured storage heaters and 82% used electric immersion to provide hot water
- The 1990 baseline assumptions for case study group D are in line with these observations.

Gas heated dwellings

- It is unlikely that data will be available describing the efficiency of the boiler installed in the 1990 property, therefore it will be necessary to refer to the assumptions detailed within the SAP methodology: Appendix S assumes pre 1998 gas boilers are not fan-assisted, which corresponds to an efficiency of

66% (with the exception of a regular floor mounted boiler installed pre 1979 which has an assumed efficiency of 56%).
- Should any of the efficiency adjustments outlined in Table 4c be applicable, the boiler efficiency may be reduced by 5%. This means a regular, non-condensing, pre-1998 gas boiler (not fan assisted) without any thermostatic control of room temperature will be assumed to have an overall efficiency of 61%.

Recommendations:
- Reference should be made to Appendix E of the main report regarding the 1990 baseline assumption for loft insulation.
- A count of the chimneys and/or flues should be included for dwellings constructed between 1945 and 1964.
- The minimum efficiency assumed for the boiler winter seasonal efficiency (applied for the space heating requirement) should be no less than 61%.

Case Study Group D: SHQS 2015

- Case study group D features 25mm of factory applied foam insulation to the hot water tank. As long as the pipes are insulated, or contribute to the space heating requirement, the case studies will comply with element 33 of Annex C.
- Sub-elements 34A and 34B require that the property features a full central heating system addressing all habitable rooms (excluding the kitchen and bathroom), and that it is deemed efficient. Both the storage heaters and gas boiler specified for the baseline property meet the necessary criteria.
- Both the electric and gas heated versions of case study 9 exceed the minimum SAP rating in the 1990 baseline state. Cavity wall insulation is therefore the only measure necessary to meet all the requirements associated with Annex C of the SHQS.

Walls
- Based on element 31 of Annex C for the SHQS, cavity wall insulation must be installed for all the case study dwellings in group D.
- The RdSAP assumptions specify a U-value of 0.50 $W/m^2.K$ for a filled cavity wall constructed in Scotland between 1950 and1964. The default RdSAP assumption for insulated „system build" wall construction demonstrates poorer thermal properties (0.6 $W/m^2.K$), and as such will experience greater challenges to realising the necessary SHQS SAP rating.

Roof
- Element 32 of Annex C is not applicable to case study 9, where it cannot accommodate loft insulation.
- A minimum loft insulation thickness of 100mm is necessary for case studies 10 and 11, to meet compliance with element 32 of Annex C for the SHQS.

Electric Heating

Roof
- To exceed the minimum SAP rating (for element 35 of Annex C), it is necessary to increase the loft insulation thickness to 250mm for the electric heated case studies, 10E and 11E.

Glazing

- Case study 10E also requires the installation of pre-2003 double glazing to meet compliance with element 35 of Annex C.
- The selection of post-2003 glazing over pre-2003 glazing emphasises the challenge faced by case study 11E to comply with element 35 of Annex C, where it just exceeds the minimum SAP rating by two points.

Space and water heating

- Free-standing large volume electric storage systems may be deemed efficient as long as they were installed after 1984, however it is necessary for case studies 10E and 11E to upgrade to an improved system to help exceed the minimum SAP rating for element 35 of Annex C.
- The proposed fan storage heater will have the same efficiency, but will benefit from increased „responsiveness‟[11] and automatic controls. This will contribute to reduced space heating requirements, fuel costs and consequently a better SAP rating.
- The improved hot water tank insulation (from a thickness of 25mm to 80mm), identifies an additional effort by which landlords can help realise the necessary SAP rating for element 35.

Renewables: Solar PV to 10% of roof area

- Photovoltaic technology (specified for case study 11E) will only be suitable for a limited number of properties, where they meet sufficient criteria to ensure the effective operation of the technology (e.g. suitable orientation, sufficient space on the roof, optimal angle of roof, minimal over shading).
- Should optimal conditions associated with any of the above criteria not be met, additional costs may be incurred to try optimise operational conditions (e.g. investment in a supporting frame to improve the tilt angle, or multiple inverters to minimise the impact of partial shading for periods of the day).
- Where solar PV is potentially limited in its suitability for some dwellings, it is suggested that the technology be reserved for consideration as part of the „advanced measures 2050‟ stage.

Gas Heating

Roof

- A loft insulation thickness of only 100mm is needed for case studies 10G and 11G to meet compliance with element 32 of Annex C.

Recommendations:

- Alternative technologies should be considered to help case study 11E achieve the minimum SAP rating for the SHQS over solar PV, where the suitability of this technology is limited in relation to a number of building specific characteristics.

[11] „Table 4a: Heating Systems (space and water)‟, SAP 2009 v9.90

Case Study Group D: Further measures 2020

- The EESSH outlines a minimum EI rating to be achieved for electric and gas heated dwellings, which are:
  - C (70) and C (80) respectively for a mid- floor flat,
  - D (55) and C (70) respectively for a mid-terrace house, and
  - E (50) and D (65) respectively for an end-terrace/semi-detached house.
- Case study 10E has already met the necessary EI rating for EESSH, based on the measures installed during the „SHQS 2015" improvement stage, and no additional measures are required.
- A number of additional measures are necessary to realise the aforementioned EI rating for case studies 9 and 11, as well as the gas heated case study 10G.
- Despite this, no additional measures are considered for case study 11E, therefore it just falls short of meeting the necessary EI rating (by 1 point) until application of the „advanced measures 2050".

Electric heated dwellings

Glazing

- One of the improvement measures proposed for case study 9E is the replacement of the single glazing with double glazing.
- RdSAP assumes a U-value of 3.1 W/m^2.K and 2.0 W/m^2.K for pre-2003 and post-2003 double glazing specifications respectively, however the latter is a more appropriate specification for future improvements, and consequently any suggested under the „further measures 2020" stage.
- Post-2003 glazing may not be an appropriate specification for similar dwelling types, should social landlords have already installed double glazing prior to 2003.

Space and hot water heating

- The fan storage heaters, specified for case study 9E, will have the same efficiency as the older storage systems but benefit from increased „responsiveness"[12] and automatic controls. This will contribute to a reduction in the space heating requirement, and consequently an improved EI rating.
- The improved hot water tank insulation (increased from 25mm to 80mm) identifies another method by which landlords can reduce the hot water energy consumption, CO_2 emissions and consequently EI rating.

Gas Heating

Roof

- It has been necessary to increase the loft insulation thickness to 250mm (in addition to upgrading the heating system) to exceed the minimum EI rating for case studies 10G and 11G.

[12] „Table 4a: Heating Systems (space and water)"

Space and water heating

- The indicative life expectancy for a condensing boiler is in the region of 15 years[13], therefore installation of a new system is appropriate for both the „SHQS 2015" or „Further Measures 2020" improvement stages. This also provides an opportunity to upgrade the control strategy.
- Table 4b of the SAP methodology specifies a non-condensing combi-boiler to have an efficiency of 70-74%. Any installations after 2005 will be condensing systems, thus assume an efficiency of 80-84%. The case study control specification indicates that the system does not qualify for any efficiency adjustments detailed in table 4c of the SAP methodology.
- Improved boiler efficiency will yield considerable space heating and hot water energy reductions. Standard 6.3 of the Domestic Technical Handbook specifies a minimum seasonal efficiency of 88% (SEDBUK 2009) for gas boilers. It is proposed that this value is used to describe the efficiency for any future installations, where it represents the current minimum standards.
- A more efficient boiler will use less energy to address the load on the heating system. Any *savings* realised by a measure which reduces the load on the heating system will be greater under the operation of a less efficient boiler compared to a more efficient system. This is important to bear in mind when considering the cumulative effect of implementing energy efficiency measures installed over a number of stages: the benefits of individual measures cannot be added together.

Recommendations:

- Additional retrofit measures should be considered for case study 11E to ensure it meets compliance with the EESSH under the „further measures 2020" stage.
- An assumed gas boiler efficiency of 88% is proposed in line with the minimum standards outlined by Standard 6.3 of the Domestic Technical Handbook.
- Social landlords should be reminded that the case studies demonstrate the cumulative application of efficiency measures over three stages, and the potential benefits realised by a single measure are subject to change in relation to the other measures in place.

Case Study Group D: Advanced measures 2050

Floor

- Floor insulation is proposed for electric and gas heated versions of case studies 10 and 11 (where it cannot be accommodated by case study 9).
- The installation of floor insulation is a particularly disruptive process, and would likely incur additional expense for the duration of the work, where occupants may need to be provided with alternative accommodation and their possessions put into storage. Despite this, the installation of other improvement measures which require the floorboards to be raised, such as

[13] „Indicative life expectancy for building services plant, equipment and systems", http://www.cibse.org/pdfs/newOOMtable1.pdf

the installation of a central heating system, may provide an opportunity to install the floor insulation with minimal additional disruption.

- The installation of 50mm of floor insulation improves the U-value of a solid ground floor from 0.48 W/m^2.k to 0.27 W/m^2.K for case study 10, and from 0.74 W/m^2.k to 0.35 W/m^2.K for case study 11.

Renewables: Solar PVs to 20% of roof

- Photovoltaic technology (considered only for case study 10E, 10G and 11E) will only be suitable for a limited number of properties, where they meet sufficient criteria to ensure the effective operation of the technology (e.g. suitable orientation, sufficient space on the roof, optimal angle of roof, minimal over shading). This means consideration of this technology is most suitable under the „advanced measures 2050" stage, however this does not imply that social landlords cannot implement this technology sooner.
- Should optimal conditions associated with any of the above criteria not be met, additional costs may be incurred to try optimise operational conditions (e.g. investment in a supporting frame to improve the tilt angle, or multiple inverters to minimise the impact of partial shading for periods of the day).

Electric Heating

Glazing

- Post-2003 double glazing is included as an „Advanced Measure 2050" for case study 10E, where (i) it is unlikely be implemented in the near future subject to „pre-2003" glazing being one of the previous improvement efforts for the electric heated dwelling, and (ii) it is being considered as a future improvement.

Gas Heating

Glazing

- Post-2003 double glazing is included as an „Advanced Measure 2050", where (i) none of the gas heated dwellings have yet upgraded from single glazing (as it has not been necessary to help meet the necessary SAP and EI ratings for the SHQS and EESSH), and (ii) it is being considered as a future improvement.
- The landlord can clearly identify the extent of the benefits this measure brings for case study 9G where it is the only „advanced measure 2050" applied.

Recommendations:

- There are no recommended changes to the assumptions specified for the „Advanced Measures 2050" improvement stage, for case study group D.

Case Study Group E

12. 1976-1983 mid floor flat, 60m²

13. 1976-1983 mid-terrace house, 84m²

14. 1976-1983 semi-detached house, 108m²

Case Study Group E: 1990 Baseline

Walls

- 1093 tenement dwellings were identified by the 1991 SHCS as belonging to the social housing sector and constructed between 1965 and 1990:
  - 95% of these featured cavity wall construction.
  - Almost half (47%) were noted to feature insulation to all external walls.
- 1210 mid-terrace, end-terrace and semi-detached dwellings were identified by the 1991 SHCS as belonging to the social housing sector and constructed between 1965 and 1990:
  - 578 of these were mid-terrace dwellings, of which 91% featured cavity wall construction.
  - 632 of these were end-terrace or semi-detached dwellings, of which 93% featured cavity wall construction.
  - 43% of the 1210 dwellings were noted to feature insulation to all external walls.
- This SHCS age group spans 25 years, therefore where case study group „E" describes the earlier half of this period of construction, the 1990 baseline assumption of „no wall insulation" is considered acceptable.
- The RdSAP methodology assumes a wall U-value of 1.0 W/m^2.K for age band F cavity walls (as built) in Scotland (v9.90 and v9.91).

Ground Floor

- Where it is not possible to determine the level of floor insulation, the RdSAP methodology assumes a solid floor with no insulation for Scottish dwellings constructed between 1930 and1991 (RdSAP age bands C to G).
- Based on the calculation detailed in section S5.4 of Appendix S, the U-value calculated for case studies 13 and 14 are 0.67 W/m^2.K and 0.62 W/m^2.K respectively.

Roof

- The majority of 1965 to 1990 social rented houses (mid-terrace, end-terrace and semi-detached only), surveyed for the 1991 SHCS, featured a satisfactorily level of loft insulation (85%), defined then as 100mm. This has required further investigation to determine the validity of the baseline assumption, as discussed in Appendix E of the main report.

Glazing

- The 1991 SHCS identified 1093 social rented tenements constructed between 1965 and 1990, of which 63% featured single glazing, although 31% were noted to feature full double glazing.
- The majority of the 1210 social rented houses (mid-terrace, end-terrace and semi-detached only) constructed between 1965 and 1990, surveyed by the 1991 SHCS, featured single glazing (66%), although 26% were noted to feature full double glazing.

- For this SHCS age group, the improved specification may be more predominant in construction occurring after 1983, therefore single glazing seems an appropriate 1990 baseline assumption for case study group E.

Ventilation: Chimneys

- The 1991 SHCS indicates that only 11% of social rented tenements, and 30% of social rented houses (mid-terrace, end-terrace and semi-detached only), constructed between 1965 and 1990, featured a gas or solid fuel fire. The 1990 baseline assumption of „no open chimneys" is therefore considered appropriate.

Space and water heating

- Case study group E specifies factory applied foam insulation thickness of 25mm for the hot water cylinder. This is better than the default performance specification (12mm loose jacket) assumed by RdSAP for hot water cylinders in post-1965 constructed Scottish dwellings. It is not until after 1984 that 25mm factory applied foam insulation is the default RdSAP assumption

Electric heated dwellings

Space and water heating

- Based on observations from the 1991 SHCS:
    - 78% of electric heated, social rented tenement dwellings, constructed between 1965 and 1991, featured storage heaters and 90% used electric immersion to provide hot water.
    - 74% of electric heated, social rented mid-terrace, end-terrace and semi-detached houses, constructed between 1965 and 1991, featured storage heaters and 88% used electric immersion to provide hot water.
- The 1990 baseline assumptions reflect these observations.

Gas heated dwellings

Space and water heating

- It is unlikely that data will be available describing the efficiency of the boiler installed in the 1990 property, therefore it will be necessary to refer to the assumptions detailed within the SAP methodology: Appendix S assumes pre 1998 gas boilers are not fan-assisted, which corresponds to an efficiency of 66% (with the exception of a regular floor mounted boiler installed pre 1979 with an assumed efficiency of 56%).
- Should any of the efficiency adjustments outlined in Table 4c of the SAP methodology be applicable, the boiler efficiency may be reduced by 5%. This means a regular, non-condensing, pre-1998 gas boiler (not fan assisted) without any thermostatic control of room temperature will be assumed to have an overall efficiency of 61%.

Recommendations:

- Reference should be made to Appendix E of the main report in relation to the 1990 baseline assumption for loft insulation.
- The minimum efficiency assumed for the boiler winter seasonal efficiency (applied for the space heating requirement) should be no less than 61%.

- The case studies feature 25mm of factory applied foam insulation to the hot water tank. As long as the pipes are insulated, or contribute to the space heating requirement, both 12E and 12G comply with element 33 of Annex C.
- Sub-elements 34A and 34B require that the property features a full central heating system addressing all habitable rooms (excluding the kitchen and bathroom), and that it is deemed efficient. Both the storage heaters and gas boiler specified for the baseline property meet the necessary criteria
- The 1990 baseline forms of case study 12 (both electric and gas heated) meet the minimum SAP criteria required for element 35 of Annex C, therefore only cavity wall insulation is required to comply with the other elements.

Walls

- Based on element 31 of Annex C for the SHQS, cavity wall insulation must be installed for all the dwellings.
- The RdSAP assumptions specify a U-value of 0.40 $W/m^2.K$ for a filled cavity wall constructed in Scotland between 1976 and 1983.

Roof

- Element 32 of Annex C is not applicable to case study 12, where it cannot accommodate loft insulation.
- A loft insulation thickness of at least 100mm is necessary for case studies 13 and 14 to meet compliance with element 32 of Annex C for the SHQS.

Electric heated dwellings

Roof

- It is necessary to increase the loft insulation thickness to 250mm for case study 14E, to exceed the minimum SAP rating, in line with element 35 of Annex C.

Glazing

- Case study 13E is reliant on the installation of double glazing to help exceed the minimum SAP rating. Specification of pre-2003 glazing allows landlords to view the potential benefits associated with this measure, whilst providing flexibility to choose better glazing specifications to realise the SAP rating should they not be able to accommodate any of the other energy efficiency measures considered.
- The selection of post-2003 glazing over pre-2003 glazing, for case study 14E, emphasises the challenge this dwelling faces to comply with element 35 of Annex C, where it just exceeds the minimum SAP rating by two points

Space and water heating

- Free-standing large volume electric storage systems may be deemed efficient as long as they were installed after 1984, however it may be necessary to upgrade to an improved system to help exceed the minimum SAP rating for element 35 of Annex C.
- The fan storage heaters, proposed for case studies 13E and 14E, will have the same efficiency as the previous system, but will benefit from increased „responsiveness"[14] and automatic controls. This will contribute to reduced space heating requirements, fuel costs and consequently a better SAP rating.

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[14] „Table 4a: Heating Systems (space and water)", SAP 2009 v9.90

Gas Heated dwellings

Glazing

- Case study 14G is reliant on the installation of double glazing to help exceed the minimum SAP rating. Specification of pre-2003 glazing allows landlords to view the potential benefits associated with this measure, whilst providing flexibility to choose better glazing specifications to realise the SAP rating should they not be able to accommodate any of the other energy efficiency measures considered.

Recommendations:

- There are no recommended changes to the assumptions specified for the „SHQS 2015" improvement stage for case study 12.

Case Study Group E: Further measures 2020

- The EESSH outlines a minimum EI rating to be achieved for electric fuelled properties and gas fuelled properties. These are:
  - a C (70) and C (80) respectively for a mid-floor flat,
  - a D (55) and C (70) respectively for a mid-terrace house, and
  - an E (50) and D (65) respectively for an end-terrace or semi-detached house.
- No additional measures are suggested under this stage for case study 14E, where the work undertaken to meet compliance with the „SHQS 2015" mean it has also exceeded the minimum EI rating for the EESSH.
- Additional measures are proposed for case study 13E, however it just falls short of the minimum EI rating (by 1 point) therefore does not meet compliance with the EESSH until application of the „advanced measures 2050".

Roof

- Where feasible (and if not undertaken as a prior measure), the loft insulation thickness is increased to 250mm for the electric and gas heated dwellings (i.e. case studies 13E, 13G and 14G).

Electric Heating

Glazing

- Case study 12E specifies the replacement of its single glazing with post-2003 double glazing to help exceed the minimum EI rating.
- RdSAP assumes a U-value of 3.1 W/m^2.K and 2.0 W/m^2.K for pre-2003 and post-2003 double glazing specifications respectively, however the latter is a more appropriate specification for future improvements, and consequently any suggested under the „further measures 2020" stage.
- This may not be a suitable measure for similar dwelling types, should the glazing have previously been upgraded to „pre-2003" double glazing standards.

Space and water heating

- The proposed fan storage heater will have the same efficiency as the older storage systems, but will benefit from increased „responsiveness"[15] and

[15] „Table 4a: Heating Systems (space and water)", SAP 2009 v9.90

automatic controls, contributing to reduced space heating requirements, and consequently an improved EI rating.

- The improvement to the hot water tank insulation, increasing the factory applied foam insulation thickness from 25mm to 80mm, identifies another method by which landlords can reduce the hot water energy consumption, CO_2 emissions and consequently EI rating.

Gas heated dwellings

Glazing

- Case studies 12G and 13G specify the replacement of single glazing with post-2003 double glazing to help exceed the minimum EI rating.
- RdSAP assumes a U-value of 3.1 $W/m^2.K$ and 2.0 $W/m^2.K$ for pre-2003 and post-2003 double glazing specifications respectively, however the latter is a more appropriate specification for future improvements, and consequently any suggested under the „further measures 2020" stage.
- This may not be a suitable measure for similar dwelling types, should the glazing have previously been upgraded to „pre-2003" double glazing standards.

Space and water heating

- The indicative life expectancy for a condensing boiler is in the region of 15 years[16], therefore installation of a new system is appropriate for both the „SHQS 2015" or „Further Measures 2020" improvement stages. This also provides an opportunity to upgrade the control strategy.
- Table 4b of the SAP methodology specifies a non-condensing combi-boiler to have an efficiency of 70-74%. Any installations after 2005 will be condensing systems, thus assume an efficiency of 80-84%. The case study control specification indicates that the system does not qualify for any efficiency adjustments detailed in table 4c of the SAP methodology.
- Improved boiler efficiency will yield considerable space heating and hot water energy reductions. Standard 6.3 of the Domestic Technical Handbook specifies a minimum seasonal efficiency of 88% (SEDBUK 2009) for gas boilers. It is proposed that this value is used to describe the efficiency for any future installations, where it represents the current minimum standards.
- A more efficient boiler will use less energy to address the load on the heating system. Any *savings* realised by a measure which reduces the load on the heating system will be greater under the operation of a less efficient boiler compared to a more efficient system. This is important to bear in mind when considering the cumulative effect of implementing energy efficiency measures installed over a number of stages: the benefits of individual measures cannot be added together.

Recommendations:

- Case study 13E should consider additional measures (such as increasing the hot water system insulation thickness) to ensure it meets compliance with the EESSH minimum EI rating.

[16] „Indicative life expectancy for building services plant, equipment and systems", http://www.cibse.org/pdfs/newOOMtable1.pdf

- An assumed gas boiler efficiency of 88% is proposed in line with the minimum standards outlined by Standard 6.3 of the Domestic Technical Handbook.
- Social landlords should be reminded that the case studies demonstrate the cumulative application of efficiency measures over three stages, and the potential benefits realised by a single measure are subject to change in relation to the other measures in place.

Case study Group E: Advanced measures 2050

- No additional measures are considered for case study 12 (electric or gas heated) under the „advanced measures 2050" stage.

Floor

- The installation of floor insulation is a particularly disruptive process, and would likely incur additional expense for the duration of the work, where occupants may need to be provided with alternative accommodation and their possessions put into storage. Despite this, the installation of other improvement measures which require the floorboards to be raised, such as the installation of a central heating system, may provide an opportunity to install the floor insulation with minimal additional disruption.
- The installation of 50mm of floor insulation improves the U-value of a solid ground floor from 0.67 $W/m^2.k$ to 0.33 $W/m^2.K$ for case study 13, and from 0.62 $W/m^2.k$ to 0.32 $W/m^2.K$ for case study 14.

Renewables: Solar PVs to 20% of roof

- Photovoltaic technology, specified for case studies 13 and 14, will only be suitable for a limited number of properties, where they meet sufficient criteria to ensure the effective operation of the technology (e.g. suitable orientation, sufficient space on the roof, optimal angle of roof, minimal over shading).
- Should optimal conditions associated with any of the above criteria not be met, additional costs may be incurred to try optimise operational conditions (e.g. investment in a supporting frame to improve the tilt angle, or multiple inverters to minimise the impact of partial shading for periods of the day).

Electric heated dwellings

Glazing

- Post 2003 double glazing is included as an „Advanced Measure 2050" for case study 13E, where it is unlikely be implemented in the near future subject to „pre-2003" glazing being one of the previous improvement efforts for the electric heated dwelling.

Space and water heating

- The improvement to the hot water tank insulation for case study 13E, increasing the factory applied foam insulation thickness from 25mm to 80mm, identifies another method by which landlords can reduce the hot water energy consumption, CO_2 emissions and consequently EI rating.
- Had this been specified as an „SHQS 2015" or „further measures 2020" improvement, case study 13E may have been able to meet compliance with the EESSH criteria earlier in the process.

Gas Heating

Glazing

- Post 2003 double glazing is included as an „Advanced Measure 2050" for case study 14G, where it is unlikely be implemented in the near future subject to „pre-2003" glazing being one of the previous improvement efforts for the gas heated dwelling.

Recommendations:

- Specification of 80mm factory applied foam for the electric immersion hot water system may be better suited under a previous improvement stage, to help the dwelling meet the necessary criteria for the EESSH.

Case Study Group F

1. **1984-1991 mid floor flat, 60m²**
2. **1984-1991 mid terrace house, 76m²**
3. **1984-1991 semi-detached house, 74m²**

Case Study Group F: 1990 Baseline

Walls

- 1093 tenement dwellings were identified by the 1991 SHCS as belonging to the social housing sector and constructed between 1965 and 1990:
  - 95% of these featured cavity wall construction.
  - Almost half (47%) were noted to feature insulation to all external walls.
- 1210 mid-terrace, end-terrace and semi-detached dwellings were identified by the 1991 SHCS as belonging to the social housing sector and constructed between 1965 and 1990:
  - 578 of these were mid-terrace dwellings, of which 91% featured cavity wall construction.
  - 632 of these were end-terrace and semi-detached dwellings, of which 93% featured cavity wall construction.
  - 43% of the 1210 dwellings were noted to feature insulation to all external walls
- This SHCS age group spans 25 years, therefore for case study group „F", describing the latter half of this period of construction, it is considered appropriate to assume wall insulation is present.
- The RdSAP methodology assumes a wall U-value of 0.35 W/m^2.K for age band G filled cavity walls in Scotland (v9.90 and v9.91).

Ground Floor

- Where it is not possible to determine the level of floor insulation, the RdSAP methodology assumes a solid floor with no insulation for Scottish dwellings constructed between 1930 and 1991 (RdSAP age bands C to G).
- For case studies 16 and 17 It has been assumed that some insulation is present calculated in the region of 0.30 W/m^2.K and 0.36 W/m^2.K respectively.
- Alternatively, table S11 and S12 in the RdSAP manual can be interpreted as indicating that no insulation would be present

Roof

- The majority of post 1965 mid-terrace houses from the social housing stock (87%), surveyed for the 1991 SHCS, featured a satisfactorily level of loft insulation, defined as 100mm in 1991. This has required further investigation to determine the validity of the baseline assumption, as discussed in Appendix E of the main report.

Glazing

- The majority of the 1093 social rented tenements, identified by the 1991 SHCS and constructed between 1965 and 1990, featured single glazing (63%), although 31% were noted to feature full double glazing.
- The majority of the 1210 social rented mid-terrace, end-terrace and semi-detached houses, identified by the 1991 SHCS and constructed between

1965 and 1990, featured single glazing (66%), although 26% were noted to feature full double glazing
- For this SHCS age group, the improved specification may be more predominant in construction occurring after 1983, therefore pre-2003 double glazing seems an appropriate 1990 baseline assumption for case study group F.

Ventilation: Chimneys
- The 1991 SHCS indicates that only 11% of social rented tenements, and 30% of social rented houses (mid-terrace, end-terrace and semi-detached only), constructed between 1965 and 1990, featured a gas or solid fuel fire, therefore the assumption of „no open chimneys" is considered appropriate.

Space and water heating
- Case study group F specifies factory applied foam insulation thickness of 25mm for the hot water cylinder. This corresponds to the default performance assumed by RdSAP for hot water cylinders in Scottish dwellings constructed between 1984 and 1991.

Electric heated dwellings

Space and water heating
- Based on observations from the 1991 SHCS:
  - 78% of electric heated, social rented tenement dwellings, constructed between 1965 and 1991, featured storage heaters and 90% used electric immersion to provide hot water.
  - 74% of electric heated, social rented mid-terrace, end-terrace and semi-detached houses, constructed between 1965 and 1991, featured storage heaters and 88% used electric immersion to provide hot water
- The 1990 baseline assumptions correspond with the above observations.

Gas heated dwellings

Space and water heating
- It is unlikely that data will be available describing the efficiency of the boiler installed in the 1990 property, therefore it will be necessary to refer to the assumptions detailed within the SAP methodology: Appendix S assumes pre 1998 gas boilers are not fan-assisted, which corresponds to an efficiency of 66% (with the exception of a regular floor mounted boiler installed pre 1979 with an assumed efficiency of 56%).
- Should any of the efficiency adjustments outlined in Table 4c of the SAP methodology be applicable, the boiler efficiency may be reduced by 5%. This means a regular, non-condensing, pre-1998 gas boiler (not fan assisted) without any thermostatic control of room temperature will be assumed to have an overall efficiency of 61%.

Recommendations:

- Reference should be made to Appendix E of the main report in relation to the 1990 baseline assumption for loft insulation.
- The minimum efficiency assumed for the boiler winter seasonal efficiency (applied for the space heating requirement) should be no less than 61%.
- For the baseline it would justifiable to model the ground floor properties F16 and F17 without floor insulation, utilising RdSAPs basic assumptions.

Case Study Group F: SHQS 2015

- The case studies feature 25mm of factory applied foam insulation to the hot water tank. As long as the pipes are insulated, or contribute to the space heating requirement, case study group F complies with element 33 of Annex C.
- Sub-elements 34A and 34B require that the property features a full central heating system addressing all habitable rooms (excluding the kitchen and bathroom), and that it is deemed efficient. Both the storage heaters and gas boiler specified for the baseline property meet the necessary criteria
- The 1990 baseline versions of case study 15, and gas heated case studies 16G and 17G, exceed the minimum SAP rating to meet compliance with Element 35 of Annex C. No additional measures are considered for these dwellings under this stage of improvements.

Electric heated dwellings

Roof

- To exceed the minimum SAP rating, in line with element 35 of Annex C, it is necessary to increase the loft insulation thickness to 250mm for case studies 16E and 17E.

Space and water heating

- Free-standing large volume electric storage systems (associated with case study 17E only) may be deemed efficient as long as they were installed after 1984, however it may be necessary to upgrade to an improved system to help exceed the minimum SAP rating for element 35 of Annex C
- The proposed fan storage heaters specified for case studies 16E and 17E will have the same efficiency as the older storage systems, but will benefit from increased „responsiveness"[17] and automatic controls, contributing to a reduction in the space heating requirement, and consequently an improved SAP rating.
- The improvement to the hot water tank insulation for 16E and 17E, increasing the factory applied foam insulation thickness from 25mm to 80mm, identifies another method by which landlords can reduce the hot water energy consumption, CO_2 emissions and consequently SAP rating.

Renewables: Solar PVs to 20% of roof

- Photovoltaic technology is specified for case study 17E, however this will only be suitable for a limited number of properties, where they meet sufficient criteria to ensure the effective operation of the technology (e.g. suitable

[17] „Table 4a: Heating Systems (space and water)"

orientation, sufficient space on the roof, optimal angle of roof, minimal over shading).
- Should optimal conditions associated with any of the above criteria not be met, additional costs may be incurred to try optimise operational conditions (e.g. investment in a supporting frame to improve the tilt angle, or multiple inverters to minimise the impact of partial shading for periods of the day).

Recommendations:
- Alternative technologies (such as improved glazing) should be considered to help case study 17E achieve the minimum SAP rating for the SHQS over solar PV, where the suitability of this technology is limited in relation to a number of building specific characteristics.

Case Study Group F: Further Measures 2020

- The EESSH outlines a minimum EI rating to be achieved for electric fuelled properties and gas fuelled properties. These are:
    - C (70) and C (80) respectively for a mid-floor flat,
    - D (55) and C (70) respectively for a mid-terrace house, and
    - E (50) and D (65) respectively for an end-terrace/semi-detached house.
- Case study 16E has exceeded the minimum EI rating based on the measures specified for the SHQS 2015 improvement stage, therefore no additional measures are considered.
- Case study 17E just falls short of the minimum EI rating, therefore does not meet compliance with the EESSH until application of the „advanced measures 2050‟.

Electric heated dwellings

Glazing
- Case study 17E specifies post-2003 double glazing under the „further measures 2020 stage, but still just falls short of the minimum EI rating to meet compliance with the EESSH. Additional measures should be suggested to try help meet compliance.

Space and water heating
- The proposed fan storage heater (for case study 15E only) will have the same efficiency as the older system, but will benefit from increased „responsiveness‟[18] and automatic controls, contributing to reduced space heating requirements, fuel costs and consequently a better SAP rating.
- The improvement to the hot water tank insulation (for case study 15E only), increasing the factory applied foam insulation thickness from 25mm to 80mm, identifies additional efforts landlords can implement to help realise a better SAP rating.

[18] „Table 4a: Heating Systems (space and water)‟, SAP 2009 v9.90

Gas heated dwellings

Roof

- Where not previously improved upon, the loft insulation thickness has been increased to 250mm for case studies 16G and 17G, to help improve the EI rating associated with the dwelling.

Glazing

- All the gas heated case studies in group F specify the installation of post-2003 glazing for the „further measures 2020" improvement stage, in an effort to help exceed the minimum EI rating.

Space and water heating

- The indicative life expectancy for a condensing boiler is in the region of 15 years[19], therefore installation of a new system is appropriate for both the „SHQS 2015" or „Further Measures 2020" improvement stages. This also provides an opportunity to upgrade the control strategy.
- Table 4b of the SAP methodology specifies a non-condensing combi-boiler to have an efficiency of 70-74%. Any installations after 2005 will be condensing systems, thus assume an efficiency of 80-84%. The case study control specification indicates that the system does not qualify for any efficiency adjustments detailed in table 4c of the SAP methodology.
- Improved boiler efficiency will yield considerable space heating and hot water energy reductions. Standard 6.3 of the Domestic Technical Handbook specifies a minimum seasonal efficiency of 88% (SEDBUK 2009) for gas boilers. It is proposed that this value is used to describe the efficiency for any future installations, where it represents the current minimum standards.
- A more efficient boiler will use less energy to address the load on the heating system. Any *savings* realised by a measure which reduces the load on the heating system will be greater under the operation of a less efficient boiler compared to a more efficient system. This is important to bear in mind when considering the cumulative effect of implementing energy efficiency measures installed over a number of stages: the benefits of individual measures cannot be added together.

Recommendations:

- Additional improvement measures should be suggested for case study 17E to ensure it can achieve the minimum EI rating for the EESSH.
- An assumed gas boiler efficiency of 88% is proposed in line with the minimum standards outlined by Standard 6.3 of the Domestic Technical Handbook.
- Social landlords should be reminded that the case studies demonstrate the cumulative application of efficiency measures over three stages, and the potential benefits realised by a single measure are subject to change in relation to the other measures in place.

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[19] „Indicative life expectancy for building services plant, equipment and systems",
http://www.cibse.org/pdfs/newOOMtable1.pdf

Case Study Group F: Advanced Measures 2050

Renewables: Solar PVs to 20% of roof or 3m^2 of solar thermal

- Solar technologies, specified for case studies 16 and 17, will only be suitable for a limited number of properties, where they meet sufficient criteria to ensure the effective operation of the technology (e.g. suitable orientation, sufficient space on the roof, optimal angle of roof, minimal over shading).
- Should optimal conditions associated with any of the above criteria not be met, additional costs may be incurred to try optimise operational conditions (e.g. investment in a supporting frame to improve the tilt angle, or multiple inverters to minimise the impact of partial shading for periods of the day).

Electric heated dwellings

Walls

- Assuming cavity wall construction, the filled cavity U-value for construction built in Scotland between 1984 and 1991 is 0.35 W/m^2.K.

Glazing

- Upgrading the glazing specification to post-2003 double glazing allows landlords to view the potential benefits from this measure. It is more suited to an „advanced measure" where it may not be necessary to replace the pre-2003 double glazing for a number of years.

Recommendations:

- There are no recommended changes to the assumptions specified for the „Advanced Measures 2050" improvement stage, for case study group F.

Case Study Group G

4. **1992-1998 mid floor flat, 70m^2**
5. **1992-1998 mid terrace house**
6. **1992-1998 semi-detached house, 74m^2**

Case Study Group G: 1990 Baseline

Walls

- Compliance with the Building Standards (Scotland) Regulations 1990 required that the elemental standard U-value of exposed walls in dwellings should not exceed 0.45 W/m^2.
- The RdSAP methodology v9.91 assumes a wall U-value of 0.45 W/m^2.K for filled cavity walls (as built) in Scotland for age band H (v9.90 and v9.91).

Ground Floor (where applicable)

- Compliance with the Building Standards (Scotland) Regulations 1990 required the elemental U-value of floors in dwellings to not exceed 0.45 W/m^2.
- Where it is not possible to determine the level of floor insulation, the RdSAP methodology assumes a solid floor with 25mm insulation for Scottish dwellings constructed between 1992 and 1998 (RdSAP age band H).
- Based on the calculation detailed in section S5.4 of Appendix S, the U-value calculated for case study 19 is in the region of 0.39 W/m^2.K which complies with the building standards in place at the time.
- The U-value calculated for case study 20 is in the region of 0.50 W/m^2.K, which is in excess of the minimum building standard criteria. Specification of 50mm floor insulation, instead of 25mm as per the RdSAP default assumption (Table S11), lowers the U-value to 0.36 W/m^2.K which complies with the minimum building standards.

Roof

- Table S9 in appendix S states an assumed roof U-value of 0.40 W/m^2.K for a slate or tile roof featuring 100mm insulation, as specified by the 1990 baseline.
- If the loft insulation thickness is not known and table S10 from Appendix S applies, dwellings constructed in Scotland between 1992 and 1998 assume a default U-value of 0.29 W/m^2.K associated with an insulation thickness of 150mm (for a pitched, slate or tile roof with insulation between joists).
- This has required further investigation to determine the validity of the baseline assumption, as discussed in Appendix E of the main report.

Glazing

- Compliance with the Building Standards (Scotland) Regulations 1990 required that the U-value associated with glazing fittings in dwellings should not exceed 3.30 W/m^2.
- This corresponds to U-value detailed in table S14 of Appendix S for double glazing in Scotland installed prior to 2003.

Space and water heating

- Case study 18E specifies a factory applied foam insulation thickness of 50mm for the hot water cylinder, whereas case studies 18G and 19G specify a thickness of 38mm. These exceed the default performance assumed by

RdSAP for hot water cylinders (25mm factory applied foam insulation) in Scottish dwellings constructed between 1992 and 1998.

- Case studies 19E, 20E and 20G specify factory applied foam insulation thickness of 25mm for the hot water cylinder. This corresponds with the default performance assumed by RdSAP for hot water cylinders in Scottish dwellings.

Gas heated dwellings

Space and water heating

- It is unlikely that data will be available describing the efficiency of the boiler installed in the 1990 property, therefore it will be necessary to refer to the assumptions detailed within the SAP methodology: Appendix S assumes pre 1998 gas boilers are not fan-assisted, which corresponds to an efficiency of 66% (with the exception of a regular floor mounted boiler installed pre 1979 with an assumed efficiency of 56%).
- Should any of the efficiency adjustments outlined in Table 4c of the SAP methodology be applicable, the boiler efficiency may be reduced by 5%. This means a regular, non-condensing, pre-1998 gas boiler (not fan assisted) without any thermostatic control of room temperature will be assumed to have an overall efficiency of 61%.

Recommendations:

- A floor insulation thickness of 50mm (greater than the 25mm default assumption) needs to be specified to ensure the floor U-value meets the building standards in place at the time.
- Reference should be made to Appendix E of the main report in relation to the 1990 baseline assumption for loft insulation.
- The minimum efficiency assumed for the boiler winter seasonal efficiency (applied for the space heating requirement) should be no less than 61%.

Case Study Group G: SHQS 2015

- The 1990 baseline wall and loft insulation specifications for case study group G are sufficient to meet compliance with elements 31 and 32 of Annex C.
- The case studies feature at least 25mm of factory applied foam insulation to the hot water tank. As long as the pipes are insulated, or contribute to the space heating requirement, case study group F complies with element 33 of Annex C.
- Sub-elements 34A and 34B require that the property features a full central heating system addressing all habitable rooms (excluding the kitchen and bathroom), and that it is deemed efficient. Both the storage heaters and gas boiler specified for the baseline property meet the necessary criteria
- The 1990 baseline versions of case study 18, and gas heated case studies 19G and 20G, exceed the minimum SAP rating to meet compliance with Element 35 of Annex C. No additional measures are considered for these dwellings under this stage of improvement

Electric heated dwellings

Roof

- To exceed the minimum SAP rating, in line with element 35 of Annex C, it is necessary to increase the loft insulation thickness to 250mm for case studies 19E and 20E.

Renewables: Solar PVs to 20% of roof

- Photovoltaic technology, specified for case studies 19E and 20E, will only be suitable for a limited number of properties, where they meet sufficient criteria to ensure the effective operation of the technology (e.g. suitable orientation, sufficient space on the roof, optimal angle of roof, minimal over shading).
- Should optimal conditions associated with any of the above criteria not be met, additional costs may be incurred to try optimise operational conditions (e.g. investment in a supporting frame to improve the tilt angle, or multiple inverters to minimise the impact of partial shading for periods of the day).

Recommendations:

- Alternative technologies should be considered to help case studies 19E and 20E achieve the minimum SAP rating for the SHQS over solar PV, where the suitability of this technology is limited in relation to a number of building specific characteristics.

Case Study Group G: Further Measures 2020

- The EESSH outlines a minimum EI rating to be achieved for electric and gas fuelled properties. These are:
  - C (70) and C (80) respectively for a mid-floor flat,
  - D (55) and C (70) respectively for a mid-terrace house, and
  - E (50) and D (65) respectively for an end-terrace/semi-detached house.
- Electric heated case studies 19E and 20E exceed the minimum EI rating, based on the measures specified for the SHQS 2015 improvement stage. Despite this, a number of additional measures are considered under the „further measures 2020‟ stage.

Electric Heating

Glazing

- Post-2003 glazing is specified for all the electric heated case studies in group G.
- This is not critical to meeting the EI rating for case studies 19E and 20E, based on the previous specification of solar PV. Only case study 18E is reliant on the improved glazing to help it exceed the minimum EI rating.

Space and water heating

- The fan storage heaters, specified for all the electric heated case studies in group G, will have the same efficiency as the previous system, but will benefit from increased „responsiveness‟[20] and automatic controls, contributing to a reduction in the space heating requirement, and consequently an improved EI rating.

[20] „Table 4a: Heating Systems (space and water)‟

- The improvement to the hot water tank insulation, increasing the factory applied foam insulation thickness to 80mm, identifies another method by which landlords can reduce the hot water energy consumption, CO_2 emissions and consequently EI rating.
- It is suggested that specified measures for case studies 19E and 20E be included as part of the „SHQS 2015" stage of improvements rather than the „Further Measures 2020". This may help eliminate the reliance on solar PV to meet the minimum SAP rating, a technology which will not be suitable for all dwellings.

Gas heated dwellings

Roof

- Increasing the loft insulation thickness to 250mm for case studies 19G and 20G, in addition to upgrading the heating system, demonstrates a significant increase in points above the minimum EI rating.

Space and water heating

- The indicative life expectancy for a condensing boiler is in the region of 15 years[21], therefore installation of a new system is appropriate for both the „SHQS 2015" or „Further Measures 2020" improvement stages. This also provides an opportunity to upgrade the control strategy.
- Table 4b of the SAP methodology specifies a non-condensing combi-boiler to have an efficiency of 70-74%. Any installations after 2005 will be condensing systems, thus assume an efficiency of 80-84%. The case study control specification indicates that the system does not qualify for any efficiency adjustments detailed in table 4c of the SAP methodology.
- Improved boiler efficiency will yield considerable space heating and hot water energy reductions. Standard 6.3 of the Domestic Technical Handbook specifies a minimum seasonal efficiency of 88% (SEDBUK 2009) for gas boilers. It is proposed that this value is used to describe the efficiency for any future installations, where it represents the current minimum standards.
- A more efficient boiler will use less energy to address the load on the heating system. Any *savings* realised by a measure which reduces the load on the heating system will be greater under the operation of a less efficient boiler compared to a more efficient system. This is important to bear in mind when considering the cumulative effect of implementing energy efficiency measures installed over a number of stages: the benefits of individual measures cannot be added together.

Recommendations:

- The measures proposed for case studies 19E and 20E should be considered as part of the „SHQS 2015" measures, in place of the solar PV, where a greater number of dwelling are more likely to be able to accommodate these over the renewable technology
- An assumed gas boiler efficiency of 88% is proposed in line with the minimum standards outlined by Standard 6.3 of the Domestic Technical Handbook.

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[21] „Indicative life expectancy for building services plant, equipment and systems", http://www.cibse.org/pdfs/newOOMtable1.pdf

- Social landlords should be reminded that the case studies demonstrate the cumulative application of efficiency measures over three stages, and the potential benefits realised by a single measure are subject to change in relation to the other measures in place.

Case Study Group G: Advanced Measures 2050

- No „advanced measures 2050" are considered for the electric heated case studies, or gas heated case study 18G.

Gas Heating

Glazing

- Upgrading the glazing specification to post-2003 double glazing for case study allows landlords to view the potential benefits from this measure. It is suited to an „advanced measure 2050" where it may not be necessary to replace the existing double glazing for a number of years (and prior specification has not been necessary to meet any of the efficiency target ratings).

Renewables: Solar PVs to 20% of roof

- Photovoltaic technology will only be suitable for a limited number of properties, where they meet sufficient criteria to ensure the effective operation of the technology (e.g. suitable orientation, sufficient space on the roof, optimal angle of roof, minimal over shading).
- Should optimal conditions associated with any of the above criteria not be met, additional costs may be incurred to try optimise operational conditions (e.g. investment in a supporting frame to improve the tilt angle, or multiple inverters to minimise the impact of partial shading for periods of the day).

Recommendations:

- There are no recommended changes to the assumptions specified for the „Advanced Measures 2050" improvement stage, for case study 19.

Case Study Group H

7. **1999-2007 mid floor flat, 73m^2**
8. **1999-2007 mid terrace house, 97m^2**
9. **1999-2007 semi-detached house, 73m^2**

Case Study Group H: 1990 Baseline

Walls

- Compliance with the Building Standards (Scotland) Regulations 1990 (1999 Amendments) required U-values for exposed walls not to exceed 0.45 W/m^2.K. This was upgraded in 2002 to a maximum U-value of 0.30 W/m^2.K (0.27 W/m^2.K for electrically heated dwellings).
- The RdSAP methodology v9.91 assumes a wall U-value of 0.45 W/m^2.K and 0.30 W/m^2.K for filled cavity walls (as built) in Scotland for age bands I and J respectively. This means it will be difficult for case study group H to be represented by a single RdSAP calculation where the period of construction traverses two different age bands.
- It is suggested the earlier RdSAP age band I is used (describing construction between 1999 and 2002) where this represents a greater challenge to improve the thermal performance.

Ground Floor

- Compliance with the Building Standards (Scotland) Regulations required floors to achieve a maximum U-value of 0.22 W/m^2.K, or 0.45 W/m^2.K depending on the amendment version of the regulations and a number of other factors.
- Where it is not possible to determine the level of floor insulation, the RdSAP methodology assumes a solid floor with 50mm or 75mm of insulation for Scottish dwellings constructed between 1999 and 2007 (RdSAP age bands I and J respectively).
- Based on the calculation detailed in section S5.4 of Appendix S, the U-value calculated for case study 22 is in the region of 0.26 or 0.22 W/m^2.K for age bands I and J respectively, and for case study 23, in the region of 0.33 or 0.26 W/m^2.K.
- Where the default assumptions associated with RdSAP age band I are applied, the floor U-values are in compliance with the minimum building standards.

Roof

- Table S9 in appendix S states an assumed roof U-value of 0.20 W/m^2.K for a slate or tile roof featuring 200mm insulation.
- If the loft insulation thickness is not known and table S10 from Appendix S applies, dwellings constructed in Scotland between 1999 and 2007 assume a default U-value of 0.26 W/m^2.K or 0.16 W/m^2.K, associated with an insulation thickness of 150mm and 250mm respectively, for a pitched, slate or tile roof with insulation between joists.
- Compliance with the Building Standards (Scotland) Regulations required pitched roofs with insulation between the joists to achieve a U-value between 0.16 and 0.25 W/m^2.K, depending on the amendment version of the regulations and a number of other factors.

- This has required further investigation to determine the validity of the baseline assumption, as discussed in Appendix E of the main report.

Glazing

- Compliance with the Building Standards (Scotland) Regulations required glazing fittings in dwellings to achieve a U-value between 1.8 and 3.3 W/m^2.K, depending on the amendment version of the regulations and a number of other factors.
- The U-value detailed in table S14 of Appendix S for double glazing in Scotland installed post 2003, as specified by the 1990 baseline standards, is 2.0 W/m^2.K which tends towards the more stringent end of the U-value range detailed above.

Electric heated dwellings

Space and water heating

- The electric heated dwellings in case study group H specify factory applied foam insulation thickness of 38mm for the hot water cylinder. This corresponds to the default performance assumed by RdSAP for hot water cylinders in 1999-2007 constructed Scottish dwellings.

Gas heated dwellings

Space and water heating

- Unless specific data can be entered with regards to the efficiency for the specific make and model of the boiler, reference will need to be made to table 4b in SAP (v9.90).
- The 1990 baseline assumes a combi-gas boiler, installed in 1998 or later. Systems installed after 2005 are likely to be condensing systems, for which table 4b specifies an efficiency of 80-84%. For non-condensing systems installed prior to 2005, table 4b specifies an efficiency of 70-74%, however based on the building standards in place for the latter half of the construction period, and default RdSAP U-values, the boiler efficiency should be assumed to be greater than 78%.
- Where the construction U-values are determined from the RdSAP age band I, a winter seasonal efficiency of 74% seems appropriate.
- The specified controls for the 1990 baseline mean the system does not qualify for any efficiency adjustments, unless it features a boiler interlock, where a 5% reduction would apply.

Recommendations:

- The construction U-value specifications should operate on the basis of the default assumptions associated with RdSAP age band I, spanning the construction period between 1999 and 2002.
- Where the earlier construction period applies, a winter boiler efficiency of 74% is recommended.

Case Study Group G: Further Measures 2020

- The EESSH outlines a minimum EI rating to be achieved for electric and gas fuelled properties. These are:
    - C (70) and C (80) respectively for a mid-floor flat,
    - D (55) and C (70) respectively for a mid-terrace house, and
    - E (50) and D (65) respectively for an end-terrace/semi-detached house.
- The 1990 baseline specifications mean all the electric and gas heated dwellings in case study group H exceed the minimum SAP and EI rating, with the exception of the gas heated case study 21G.
- Only case study 21G is reliant on the specification of additional measures to meet compliance with the EESSH, however improvements are considered for all the case studies in group H under the „further measures 2020 improvement stage.

Roof

- Where applicable, the loft insulation is increased to a thickness of 250mm for both the electric and gas heated dwellings.

Electric Heating

Space and water heating

- The proposed fan storage heaters, applicable to all the electric heated case studies, will have the same efficiency as the previous system, but will benefit from increased „responsiveness"[22] and automatic controls. This will contribute to a reduction in the space heating requirement, and consequently an improved EI rating.
- The improvement to the hot water tank insulation, increasing the factory applied foam insulation thickness to 80mm, identifies another method by which landlords can reduce the hot water energy consumption, CO_2 emissions and consequently EI rating.

Gas heated dwellings

Space and water heating

- The indicative life expectancy for a condensing boiler is in the region of 15 years[23], therefore installation of a new system is appropriate for the „Further Measures 2020" improvement stage. This also provides an opportunity to upgrade the control strategy.
- Any installations after 2005 will be condensing systems, thus assume an efficiency of 80-84%. The case study control specification indicates that the system does not qualify for any efficiency adjustments detailed in table 4c of the SAP methodology.
- Improved boiler efficiency will yield considerable space heating and hot water energy reductions. Standard 6.3 of the Domestic Technical Handbook specifies a minimum seasonal efficiency of 88% (SEDBUK 2009) for gas

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[22] „Table 4a: Heating Systems (space and water)"

[23] „Indicative life expectancy for building services plant, equipment and systems", http://www.cibse.org/pdfs/newOOMtable1.pdf

boilers. It is proposed that this value is used to describe the efficiency for any future installations, where it represents the current minimum standards.

- A more efficient boiler will use less energy to address the load on the heating system. Any *savings* realised by a measure which reduces the load on the heating system will be greater under the operation of a less efficient boiler compared to a more efficient system. This is important to bear in mind when considering the cumulative effect of implementing energy efficiency measures installed over a number of stages: the benefits of individual measures cannot be added together.

Recommendations:

- An assumed gas boiler efficiency of 88% is proposed in line with the minimum standards outlined by Standard 6.3 of the Domestic Technical Handbook.
- Social landlords should be reminded that the case studies demonstrate the cumulative application of efficiency measures over three stages, and the potential benefits realised by a single measure are subject to change in relation to the other measures in place.

Case Study Group H: Advanced Measures 2050

- „Advanced measures 2050‟ are only considered for case studies 22 and 23, both electric and gas heated.

Renewables: Solar PVs to 20% of roof

- Photovoltaic technology will only be suitable for a limited number of properties, where they meet sufficient criteria to ensure the effective operation of the technology (e.g. suitable orientation, sufficient space on the roof, optimal angle of roof, minimal over shading).
- Should optimal conditions associated with any of the above criteria not be met, additional costs may be incurred to try optimise operational conditions (e.g. investment in a supporting frame to improve the tilt angle, or multiple inverters to minimise the impact of partial shading for periods of the day).
- Considered independent of any other improvement measures, landlords can view the potential benefits associated with this technology should it be suitable for any of the dwellings featured in their stock.

Recommendations:

- There are no recommended changes to the assumptions specified for the „Advanced Measures 2050‟ improvement stage for case study H.

Appendix 1 - Group A: Validation of Impact of varying hot water tank insulation and open chimneys

Ventilation – Chimney

Case studies 1E and 1G – *pre 1919 solid wall dwelling – ground floor* were re-run to include open chimneys and compared against the baseline which assumed there were no chimneys present.

It was found that for electrically heated property, the inclusion of one open chimney:

- reduces the SAP by 2 points, from 52 to 50, both remaining within the “E” band.
- reduces the EI by 2 points, from 33 to 31, both remaining within the “F” band.
- increases the running costs by 5%
- increases the CO_2 emissions by 5%
- increases energy consumption by 5%

Increasing the amount of open chimneys to two for the electrically heated property:

- reduces the SAP by 4 points, from 52 to 48, both remaining within the “E” band.
- reduces the EI by 5 points, from 33 to 28, both remaining within the “F” band
- increases the running costs by 10%
- increases the CO_2 emissions by 11%
- increases energy consumption by 11%

It was found that for gas heated property, the inclusion of one open chimney:

- reduces the SAP by 2 points, from 51 to 49, both remaining within the “E” band.
- reduces the EI by 2 points, from 49 to 47, both remaining within the “E” band.
- increases the running costs by 3%
- increases the CO_2 emissions by 4%
- increases energy consumption by 4%

Increasing the amount of open chimneys to two for the gas heated property:

- reduces the SAP by 3 points, from 51 to 48, both remaining within the “E” band.
- reduces the EI by 5 points, from 49 to 45, both remaining within the “E” band
- increases the running costs by 7%

- increases the CO_2 emissions by 8%
- increases energy consumption by 8%

Space and water heating – hot water cylinder insulation

Case studies 1E and 1G – *pre 1919 solid wall dwelling – ground floor* were re-run to assume a loose hot water tank jacket of 12mm and compared against the baseline which assumed there 25mm of spray foam insulation was assumed.

It was found that for electrically heated property, downgrading the hot water tank insulation as above:

- reduces the SAP by 2 points, from 52 to 50, both remaining within the “E” band.
- reduces the EI by 3 points, from 33 to 30, both remaining within the “F” band.
- increases the running costs by 6%
- increases the CO_2 emissions by 7%
- increases energy consumption by 7%

It was found that for gas heated property, downgrading the hot water tank insulation as above:

- reduces the SAP by 3 points, from 51 to 48, both remaining within the “E” band.
- reduces the EI by 4 points, from 49 to 45, both remaining within the “E” band.
- increases the running costs by 7%
- increases the CO_2 emissions by 8%
- increases energy consumption by 8%

Chimney and hot water cylinder insulation combined

Case studies 1E and 1G – *pre 1919 solid wall dwelling – ground floor* were re-run to include open chimneys and a loose hot water tank jacket of 12mm. This was compared against the baseline which assumed there were no chimneys present and 25mm of spray foam insulation on the hot water tank.

It was found that for electrically heated property, the inclusion of one open chimney downgrading the hot water tank insulation:

- reduces the SAP by 5 points, from 52 to 47, both remaining within the “E” band.
- reduces the EI by 5 points, from 33 to 28, both remaining within the “F” band.
- increases the running costs by 11%
- increases the CO_2 emissions by 11%
- increases energy consumption by 12%

Increasing the amount of open chimneys to two and downgrading the hot water tank insulation for the electrically heated property:

- reduces the SAP by 7 points, from 52 to 45, both remaining within the "E" band.
- reduces the EI by 7 points, from 33 to 26, both remaining within the "F" band
- increases the running costs by 16%
- increases the CO_2 emissions by 17%
- increases energy consumption by 18%

It was found that for gas heated property, the inclusion of one open chimney and downgrading the hot water tank insulation:

- reduces the SAP by 5 points, from 51 to 46, both remaining within the "E" band.
- reduces the EI by 5 points, from 49 to 44, both remaining within the "E" band.
- increases the running costs by 11%
- increases the CO_2 emissions by 13%
- increases energy consumption by 13%

Increasing the amount of open chimneys to two and downgrading the hot water tank insulation for the gas heated property:

- reduces the SAP by 7 points, from 51 to 44, both remaining within the "E" band.
- reduces the EI by 7 points, from 49 to 42, both remaining within the "E" band
- increases the running costs by 14%
- increases the CO_2 emissions by 17%
- increases energy consumption by 17%

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