energy saving trust

Assessment of amended U-value calculations for ECO2 Cavity Wall Insulation (CWI) measures: **Methodology and summary of findings**

Prepared for Ofgem, by Energy Saving Trust

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Contents

1 Introduction

Ofgem contracted the Energy Saving Trust (EST) to undertake a desk-based assessment of amended U-value calculations submitted for ECO2 Cavity Wall Insulation (CWI) measures.

This audit comprised two parts.

1. Calculation Audit

This was an audit of just under 2,000 records of over-written CWI installations prior to 1st June 2016 (the "**Calculation Audit**"). These records comprise the U-value calculation sheet with details of how the U-value has been estimated.

The objectives of this audit were to:

a) Identify any measures with incorrectly calculated U-values, and establish how frequently this occurred.
b) Identify any measures using unrealistic input parameters to calculate the U-values, and establish how frequently this occurred.

2. Evidence Audit

This was an audit of ~100 records of over-written CWI installations after 1st June 2016 (the "**Evidence Audit**"). These records comprise the U-value checklist introduced in June 2016, along with the U-value calculation sheet and any listed supporting evidence.

The objectives of this audit were to:

a) Identify any measures with overwritten U-values since 1st June 2016 that do not meet the new requirements for evidence or calculations.
b) Identify any measures installed since 1st June 2016 where the justification for overwriting U-values is weak or invalid, and establish how frequently this occurs across different suppliers.

This document contains a description of the methodology undertaken as part of each audit, and a summary of observations made as part of this process.

1.1 Summary of results

Table 1 - Summary of number of measures audited

Total number of measures audited:	1994	
Calculation returns (pre 01/06/2016):	1893	*Section 2*
Evidence returns (post 01/06/2016):	101	*Section 3*

Table 2 - Summary of Calculation Audit results

Issue identified	Count	Percentage of audit sample
Total number of measures audited:	1893	100%
Evidence present and within permissible	1552	82%
Evidence missing or outside permissible	341	18%
Missing evidence	18	1%
Calculation inputs unusual*	315	17%
Error in calculation	5	0%
Calculation inputs unusual + error	3	0%

*This includes records with errors in the R-value of airspace layers, see Table 5 for more details.

Table 3 – Summary of Evidence Audit results

Issue identified	Count	Percentage of audit sample
Total number of measures audited	101	100%
Checklist Missing	2	2%
Checklist completed and evidenced fully	0	0%
Checklist or evidence incomplete	99	98%
No supporting evidence listed*	14	14%
Some or all listed evidence missing*	81	80%
*Photograph**	78	
*Construction Specification**	2	
*Core Sample**	1	
*Borescope Image**	1	
Some or all listed evidence insufficient*	9	9%
No source of lambda assumption listed*	76	75%

** These groups are not mutually exclusive and so cannot be summed*

2 Calculation Audit

2.1 Background

Ofgem provided to EST for audit a sample of 1,893 records (referred to as records or measures) of cavity wall installations pre-June 2016 where default RdSAP pre-installation U-values have been overwritten by bespoke U-values. The purpose of the audit was to determine whether the inputs used to calculate these bespoke U-values fell within acceptable parameters, and whether the calculation had been performed accurately.

2.2 Methodology

2.2.1 Extracting data from records

The records of U-value calculations were provided in the form of scanned pdf documents. For the majority of records (1,278 / 68%) the data held in the calculation sheet was extracted from the pdf files and captured in a database using an automated process. Common calculation sheet templates were identified, and code was written to recognise, extract and store each data item required for the audit.

Due to the quality of pdfs (handwritten, scanned etc.), and the low frequency of some templates, it was not efficient to adapt the code for all files. For those records from which the data could not be automatically extracted (615 / 32%) the data was manually entered.

Both forms of data extraction were quality checked to ensure that the data had been captured accurately.

2.2.2 Preparing the dataset

The following steps were taken to prepare the data for analysis:

Property age-bands
RdSAP age bands were added to the dataset by cross referencing measure ID with property age band data supplied by the supplies via Ofgem.

Standardised material descriptions
A large number of different descriptions of wall elements was observed across the sample of records (~280 unique names). This was harmonised to a shortened list of names which represented all the material types that were observed in the dataset. Each wall element was labelled as ‘protected’ (from the external environment) or ‘exposed’ (to the external environment) depending on their position in the structure of the wall. This resulted in a standardised list of wall element descriptions that could be mapped against the permissible values table.

Bridging elements
These were reported in different ways. In some cases, bridging elements were identified along with complete data about the assumed lambda of the bridging material. In other examples the bridging material was identified but with no information about the thermal conductivity (lambda or λ value, W/mK)

of the bridging material. And in other cases, no bridging element was identified, even though one would reasonably be expected (i.e. mortar would be expected in a leaf of bricks). Where materials were expected to have bridging elements, and it could be inferred from the calculated U-value that these had been included in the over-written U-value (through comparison of the over-written value with a re-calculation using the available inputs), these were added to the dataset.

In many cases, full data about the bridged layer was provided (thickness, lambda of main and bridge material, fraction bridged) but the bridging material type was not identified. In the dataset this is inferred based on standard construction conventions.

Surface resistances
In some cases, (particular templates) internal and external surface resistance were not included on the U-value calculation sheet for the measure. Where it could be inferred (through comparison of the over-written value with a re-calculation using the available inputs) from the calculated U-value that these resistances had been included in the over-written U-value, these were added to the dataset.

2.2.3 Permissible Values

Each material element of the wall has been checked to see that its thickness and thermal properties fit within a range of values that we could reasonably expect to see for each material. The U-value calculation sheets declare for each material element: the thermal conductivity (lambda or λ value, W/mK) and the thickness, and/or the thermal resistance (R-value ,m^2K/W). For every report, these values were checked against a table of permissible values.

The table of permissible values was put together using a combination of standard conventions for material properties (described below), desk-based research of supplier data for some uncommon materials, and the expert judgement of the EST analysts undertaking the work.

The range of permissible values were largely taken from Chapter 3 of the *CIBSE Guide A: Environmental Design (Thermal properties of building structures*). Tables within this chapter provide ranges of values for thermal conductivity, as well as typical thicknesses for elements within common wall constructions. Other lambda values were taken from *BS EN ISO 10456: Building materials and products -- Hygrothermal properties -- Tabulated design values and procedures for determining declared and design thermal values*.

For the majority of physical materials, the permissible thermal resistance values, R-values, were calculated from the conductivity and thickness values. For certain elements, such as the internal and external surface resistance, as well as the thermal resistance of any cavity and air spaces, values have been taken from *ISO 6946:2007: Building components and building elements -- Thermal resistance and thermal transmittance -- Calculation method*. This provides the established conventions for calculating the U-value of a cavity wall.

2.2.4 Performing checks and calculations

Formulas for comparing inputs against permissible values, and calculating U-values for each record were written and executed in MS Excel.

Comparing inputs against permissible values

The thickness, thermal conductivity and thermal resistance of each wall element was compared against the corresponding permissible value for that type of material, to determine (i) whether this was different from the expected "typical" value; and (ii) whether the value was within the permissible range of values which we might expect to see. In each instance where the value for a wall element fell outside of the permissible range, this measure was flagged as having a discrepancy and a measure-by-measure interpretation added to the dataset.

Calculating U-values

The U-value of each wall was also re-calculated using the inputs provided, in order to identify any inaccuracy in the calculation. This followed the methodology as set out in BS EN ISO 6946 and summarised here.

For a wall consisting of several thermally homogeneous layers, the thermal transmittance of the wall U_{TOTAL} is calculated as follows:

$$U_{TOTAL} = \frac{1}{R_{Layer\ 1}} + \frac{1}{R_{Layer\ 2}} + \cdots + \frac{1}{R_{Layer\ n}}$$

$$R = \frac{\lambda}{thickness}$$

Where λ is the thermal conductivity of the layer and R is the thermal resistance.

However, for walls with thermally inhomogeneous layers such as those made up of different materials such as bricks and mortar, U_{TOTAL} is calculated using the Combined Method as specified in BS EN ISO 6949. This is the standard U-value calculation methodology for building elements which contain repeated thermal bridges. We would expect this methodology to have been applied in all of the calculations that we audited.

The Combined Method assumes that the total thermal transmittance of the wall is the reciprocal of the mean of the upper and lower thermal resistance limits.

$$U_{TOTAL} = \frac{2}{R_{UPPER} + R_{LOWER}}$$

R_{UPPER} is given by the following expression:

$$\frac{1}{R_{UPPER}} = \frac{f_a}{R_a} + \frac{f_b}{R_b} + \cdots + \frac{f_n}{R_n}$$

Where: R_a is the thermal resistance for heat traveling in a straight line through one thermally homogenous path and R_b is the total thermal resistance for heat traveling in a straight line through another thermally homogenous path. For instance, in a wall made purely of a layer of bricks held together by mortar and lined with plasterboard, Path A would be the path through a brick and plaster, and Path B would be the path through mortar and plaster.

f_a is the percentage of the area of the wall that corresponds to Path A, and f_b is the percentage of the area of the wall that corresponds to Path B. In the example above, f_a would be the fraction of the walls area made up of bricks and f_b would be the fraction made up of mortar.

R_{LOWER} is determined by summing the R values for each layer.

$$R_{LOWER} = R_{LAYER\ 1} + R_{LAYER\ 2} + \cdots + R_{LAYER\ N}$$

For thermally inhomogeneous layers, the equivalent thermal resistance is calculated as follows:

$$\frac{1}{R_{LOWER\ LAYER}} = \frac{f'}{R'_{LAYER}} + \frac{f''}{R''_{LAYER}}$$

Where R' is the thermal resistance of the main element (e.g. brick) and R'' is the thermal resistance of the bridging element in the layer (e.g. mortar). f' will be the fraction of wall area taken up by the main element and f'' is the fraction of wall area taken up by the bridging element.

The calculated U-value for each record was compared to the reported U-value. These were reported at tolerances of 5% and 10% to accommodate any variance caused by things like rounding in the conductivity and resistance values of the reported inputs and of the final U-value.

2.2.5 Reporting

Along with this methodology and findings document, an overall report of the results of the audit was created for each supplier, with measure-by-measure reporting of those that had discrepancies against expectations.

2.3 Results

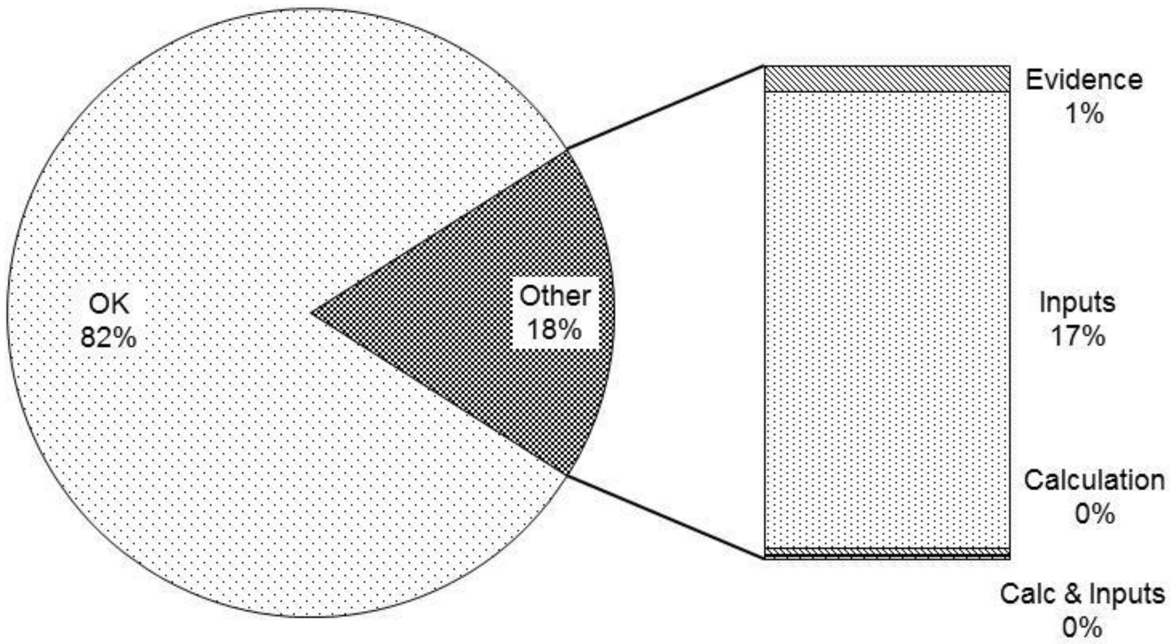
In this section we present the results of the described checks for the measures audited. Table 4 and Figure 1 summarise the headline results of the audit: the number and percentage of measures which passed all checks, the number and percentage for which some issue was identified, and a broad breakdown of the type of issue encountered.

Table 4 - Summary of audit results

Category	Frequency	Percentage
Total measures audited:	1893	100%
Evidence present and within permissible	1552	82%
Evidence missing or outside permissible	341	18%
Missing evidence	18	1%
Calculation inputs unusual*	315	17%
Error in calculation	5	0%
Calculation inputs unusual + error	3	0%

*This includes records with errors in the R-value of airspace layers.

Figure 1 - Summary of audit results



Description of discrepancy	Explanation
Missing evidence	Record missing evidence required to determine wall construction and calculate U-value
Calculation inputs	Record with calculation input(s) outside permissible values (See section 1.2.1)
Error in calculation	Records with U-value that did not match the calculation (See section 1.2.2)
Calculation inputs and error	Records with both input and U-value discrepancies

2.3.1 Missing evidence

In some cases, insufficient evidence was provided in support of the overwritten U-value to undertake the audit. The total for all measures audited can be seen in Table 4.

2.3.2 Calculation inputs

The thickness, thermal conductivity and thermal resistance of each wall element were compared against the corresponding permissible value for that type of material. Measures were also flagged where the wall was described as having only three constituent layers as this was felt likely to be an unrealistic representation of a real wall considering standard construction types.

Table 5 and Figure 2 summarise the results of this, by the type of issue that was identified.

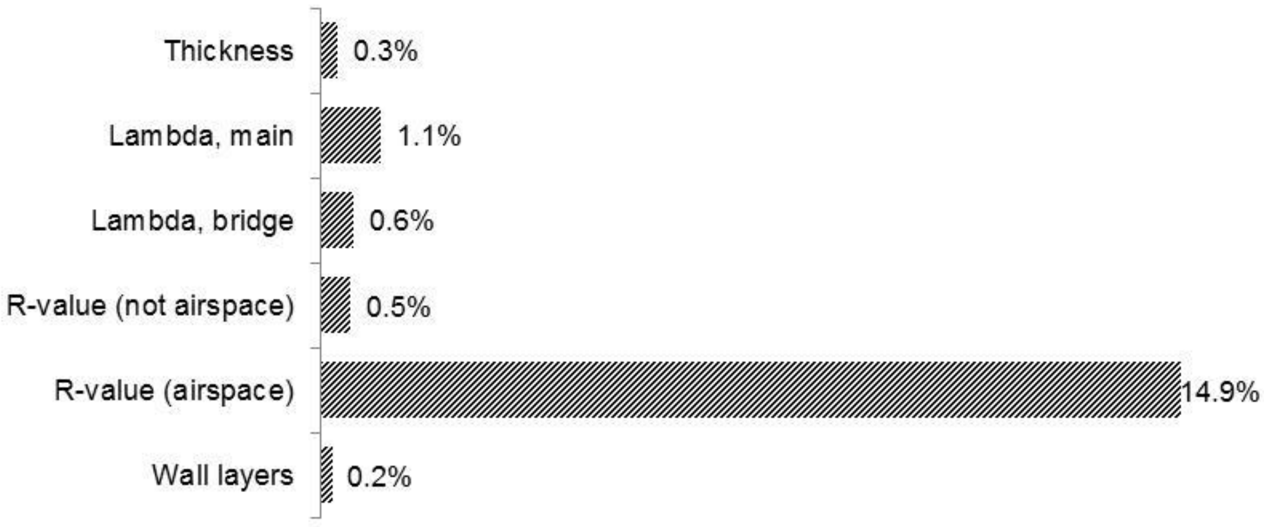
Table 5 – Comparison of calculation inputs against permissible boundaries

Type of issue	Count	Percentage of audit sample
Total with any input outside of permissible	315	17%
Thickness outside permissible*	6	0%
Lambda (main material) outside permissible*	20	1%
Lambda (bridge) outside permissible*	11	1%
R-value outside permissible*	293	15%
*Related to airspace***	283	15%
Only 3 layers in wall	4	0%

* These groups are not mutually exclusive and so cannot be summed.

** The audit revealed a number of unusual results in the R-value for airspace layers. For airspace layers, there was substantial variance in the R-value reported. These figures did not correspond with the guidance for calculating the thermal resistance of air layers in BS EN ISO 6946. Upon further investigation, this was found to be due to an error in one of the commonly used U-value calculators. Whilst this nonetheless introduced an error into the calculated U-value, this was not something which the assessors were able to adjust for and so we have not identified these as a fail but have identified these separately. Measures that failed on this airspace issue only are not considered to have failed the audit, as the untypical value was entered out of the assessor's control and can therefore not have been used to manipulate the U-value.

Figure 2: Comparison of calculation inputs against permissible boundaries



Description of input	Explanation
Thickness	Thickness of material is outside permissible boundary
Lambda, main	Thermal conductivity of main material is outside permissible boundary
Lambda, bridge	Thermal conductivity of bridging material is outside permissible boundary
R-value	Thermal resistance of material is outside permissible boundary
Wall layers	Too few wall layers are listed

2.3.3 U-value calculation

The U-value of each wall was re-calculated using the inputs provided in the U-value calculation sheets, in order to identify any inaccuracy in the calculation.

Table 6 compares the accuracy of the U-value on the record to the U-value calculated in this audit. It was determined that a small level of inaccuracy should be tolerated due to factors such as rounding in U-value, conductivity and resistance values provided in the calculation sheet. For the audit criteria, this tolerance was set at 10% - outside of which a measure was considered inaccurate.

Across the audit sample (across all suppliers) the majority of U-value calculations were completed with a very high degree of accuracy.

Table 6 – Accuracy of U-value calculation

Accuracy	Count	Percentage of audit sample
Exact or matches within 5%	1827	*96.5%*
Matches within 5-10%	40	*2.1%*
Does not match within 10%	8	*0.4%*
Calculation could not be repeated*	18	*1.0%*

** due to missing evidence*

2.4 Discussion of key results

The Calculation Audit identified a number of records for which the inputs described were unreasonable or outside of permissible expectation. The majority of these were isolated errors or discrepancies, however in the case of air layers there was a higher rate of unusual inputs.

Looking across the sample at the material and construction profile of the walls assessed we were also able to identify some deviation from expectations in the type of concrete blocks reported.

Each of these issues is discussed in this section.

2.4.1 Properties of concrete blocks

When comparing the construction profile of the sample audited against expectations of the wider UK housing stock, there are fewer walls with aerated and light density concrete blocks than we would anticipate.

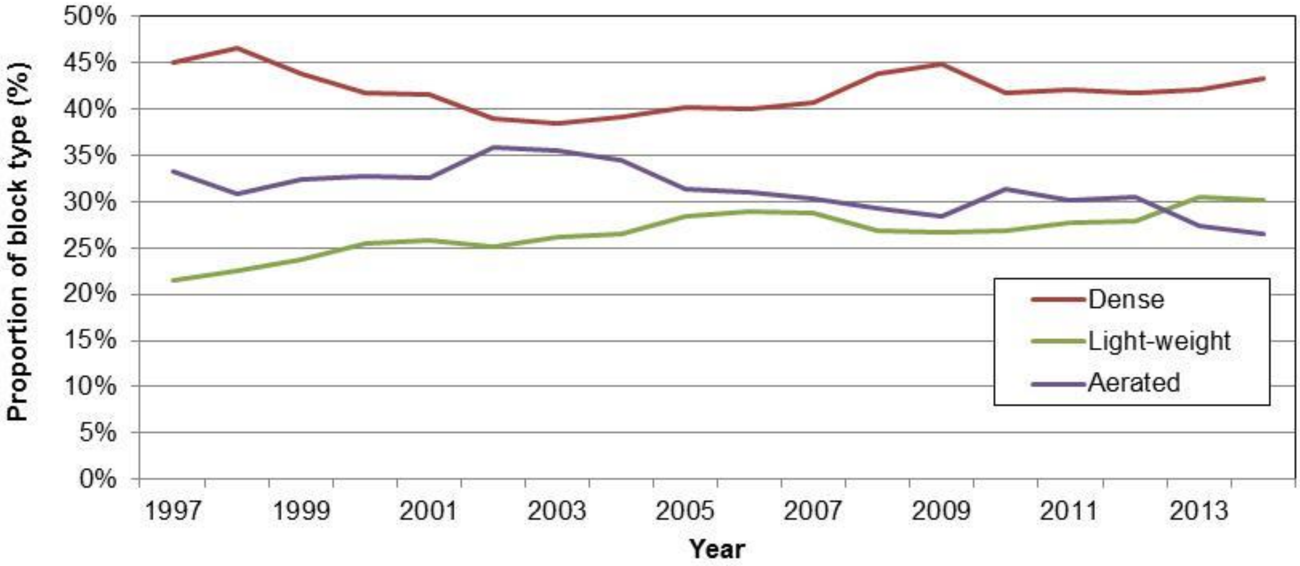
According to BEIS statistics on the production of building materials in the UK, between 1997 and 2014, 32% of the concrete blocks produced in the UK were aerated concrete and a further 27% have been light-weight (aggregate concrete, density up to 1600kg/m^3), see Table 7.

Table 7: Average proportion of concrete block production by volume in the UK between 1997 and 2014[1]

Dense	Light-weight	Aerated
42%	27%	32%

As shown in Figure 3 below, year on year the proportion of block type does not deviate by a large amount from the average. Although we do not have data preceding 1997, a representative from Concrete Block Association stated that the densities of concrete blocks in production had changed very little over the last 65 years. Therefore, given that all densities of concrete blocks are suitable for most domestic walls, we should expect to see a similar distribution of densities in concrete blocks throughout the audit.

Figure 3: Annual UK concrete block production by type of block, 1997-2014[1]



This suggests that assessors are regularly misidentifying the type of concrete block used in the calculation, more frequently recording walls as having medium-weight and heavy-weight blocks than is likely to be the case in the actual wall. This results in calculations that estimate a poorer overall U-value than the reality.

The majority of cavity walls are constructed using concrete "breeze" blocks for the inner leaf of masonry. Table 3.38 CIBSE guide defines four categories of basic concrete block: aerated (750 kg m^{-3}), light-weight (~1800 kg m^{-3}), medium-weight (~1900 kg m^{-3}) and heavy-weight (2240 kg m^{-3}). As shown in Table 8 the type of concrete block used, can have a significant impact on the thermal performance of an uninsulated cavity wall. A wall with heavy-weight blocks lets through 1.7 times as much heat as a wall with aerated concrete blocks.

Table 8: U-value of uninsulated cavity walls of typical construction* by types of concrete block used

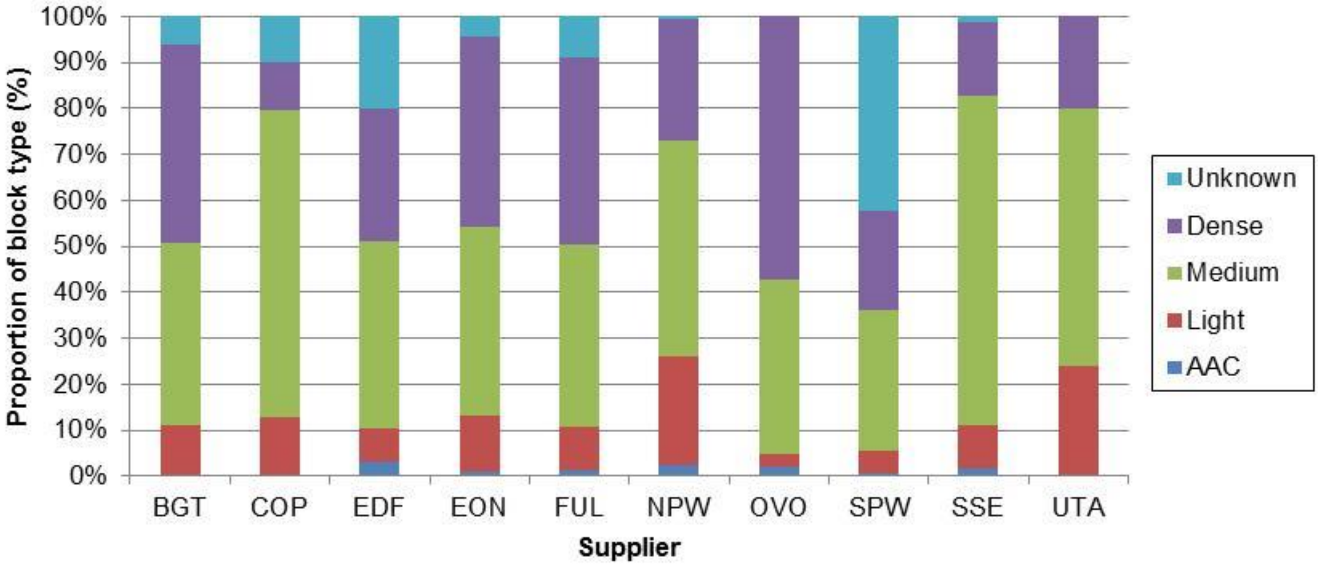
Concrete block	Aerated	Light-weight	Medium-weight	Heavy-weight
Thermal conductivity of block (W/mK)	0.15	0.55	1.13	1.90
Wall U-value using this block (W/m^{2}K)	1.07	1.51	1.71	1.81

* Construction consists of: 10mm plaster, 100mm concrete block, 70mm unventilated cavity and 100mm brick exterior

1 BEIS Monthly bulletin of building materials and components

However Figure 4 shows that there is a far lower proportion of aerated and light-weight blocks reported in our sample than corresponds to national production figures. Aerated concrete blocks were reported in 1% of records and 11% were reported to be light-weight. This suggests that a high proportion of light-weight and aerated concrete blocks are being misidentified in the calculation as either medium-weight or dense blocks, although some of the discrepancy could be attributed to the selection bias in the sample towards measures with higher U-values.

Figure 4: Proportion of concrete block type reported by each supplier



The distribution of concrete block densities was broadly similar across each supplier. Although there were a significant number of records from SPW which did not specify the density of concrete block used in the construction (listed as ‘Unknown’ in Figure 4), judging by their thermal conductivities the majority of these match dense concrete.

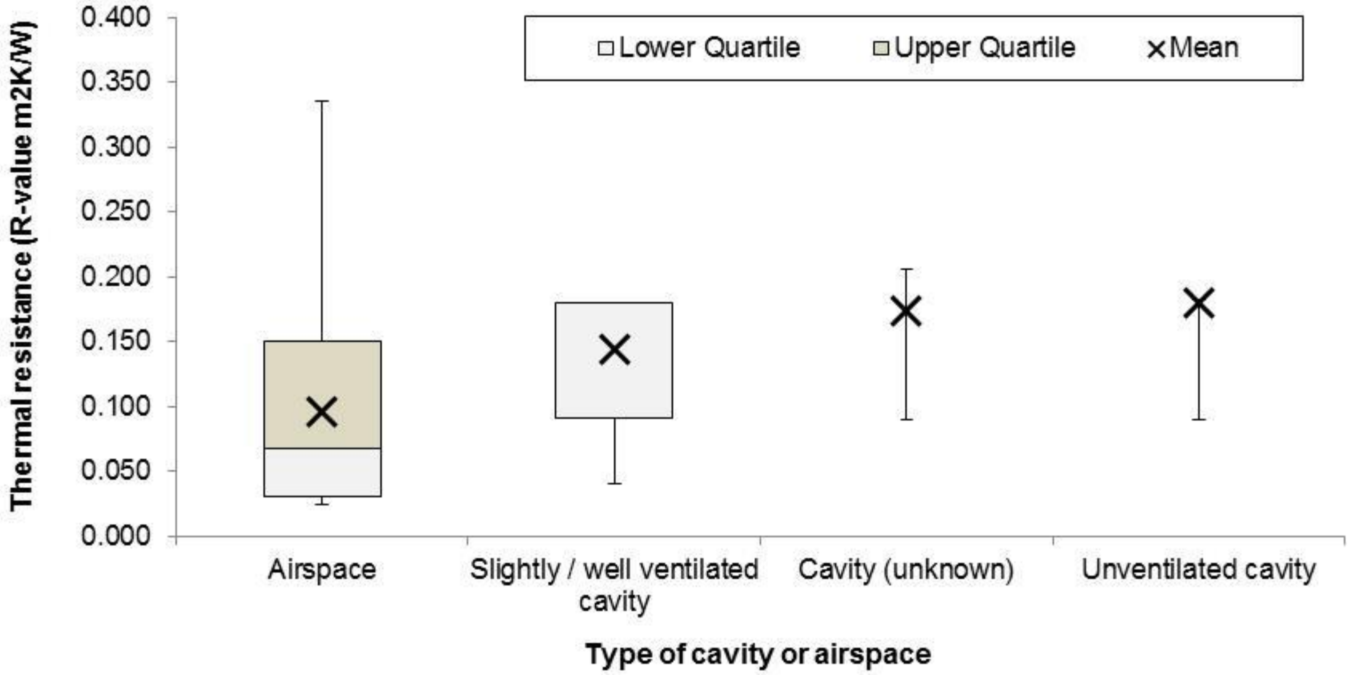
2.4.2 Thermal resistance of air layers

The second area of reported inputs for which the audit revealed a number of unusual results was in the R-value for air space and cavity layers.

Figure 5 shows the distribution of reported R-values across the audited sample, split by the broad type of air space or cavity described. These broad groupings are:

Airspace	Thin air space within a layer of the wall, for example air space between timber framing or in a plaster dabs layer.
Slightly / well ventilated cavity	Cavity with some level of ventilation; the majority were slightly ventilated with few well ventilated.
Cavity (unknown)	Cavity where the level of ventilation was not reported.
Unventilated cavity	Cavity reported as unventilated.

Figure 5 – Distribution of R-value of air space and cavity layers, by described type



The mean R-value for each follows the trend that we would expect to see: thin air space layers have lower thermal resistance than cavities, and ventilated cavities have lower thermal resistance than unventilated cavities. As expected, there was very little spread in the R-value reported for unventilated cavity walls (and those where ventilation level was not reported appear to be largely unventilated), and almost all of these measures reported an R-value of 0.18 m^2K/W – which is the standard thermal resistance specified in BS EN ISO 6946.

It is difficult to make an assessment of the R-value for cavities with ventilation due to the information required to calculate this. The formula for determining the R-value of a slightly ventilated air layer, as specified in BS EN ISO 6946, requires information on the proportion of openings to the external environment of area, A_v, per metre of length of wall. This information isn't provided as part of the calculation sheet returned for the measures.

$$R_{\mathrm{T}} = \frac{1500 - A_{\mathrm{V}}}{1000} R_{\mathrm{T,u}} + \frac{A_{\mathrm{v}} - 500}{1000} R_{\mathrm{T,v}}$$

Where $R_{T,u}$ is the thermal resistance of an unventilated layer and $R_{T,v}$ is the thermal resistance of a well-ventilated layer. This means that a ventilated cavity could have an R-value ranging between 0.18 m^2K/W (the R-value for an unventilated cavity) and 0.04 m^2K/W (the R-value for a well ventilated cavity, in which thermal resistance of the outer layer(s) is disregarded and the surface resistance for a high-emissivity surface is used)[2].

2 BS EN ISO 6946

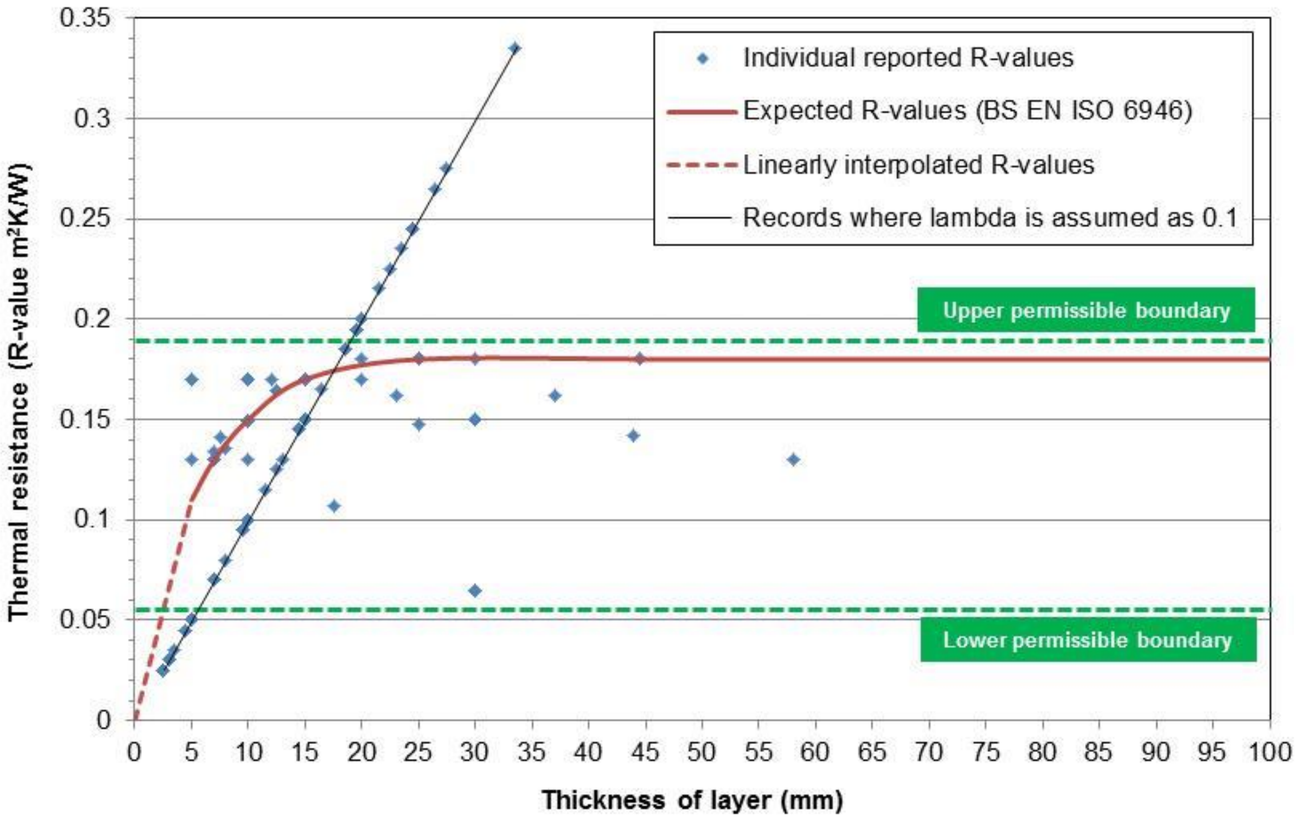
For airspace layers there is, however, substantial variance in the R-value reported. These do not correspond with the guidance for calculating the thermal resistance of air layers in BS EN ISO 6946. Figure 6 plots the thermal resistance (m2K/W) for each airspace layer in the audited dataset against its thickness. Also shown are the thermal resistances for unventilated air layers with high emissivity surfaces (all wall materials are assumed to be high emissivity unless otherwise identified) of differing thicknesses provided in Table 2 in the BS EN ISO 6946. This is provided for thicknesses of 5, 7, 10, 15, 25, 50 and 100mm, interpolated between these (solid line), and linearly interpolated between 0 and 5mm (dotted line) as per the guidance in the British Standard.

Figure 6 highlights that for many of these airspace inputs, a linear relationship between thermal resistance and thickness has been assumed – seen as the straight line of blue dots joined by a black trend line. Inspecting these measures further reveals that a thermal conductivity (lambda) value of 0.1 W/mK has been assumed for all airspaces. This is inconsistent with the guidance in BS EN ISO 6946.

The result of this assumption is that the R-value of many air layers differs from expectation. The audit has used a fixed permissible range for R-values rather than implementing a bespoke permissible range for each measure, accordingly only a sub-set of these fall outside the permissible range (shown in green). However, also clear from Figure 4 is that many of those within the permissible boundaries also diverge from the expected value.

On investigation of the measures for which this assumption was seen it was determined that in one of the most commonly used calculators, the Stroma FSAP U-value calculator, this assumption was used by all assessors. EST and Ofgem contacted Stroma to raise this question, and they confirmed that this “was a calculation issue which [they] resolved some time ago.” It was agreed with Ofgem that where calculations were undertaken using this assumption, the assessor would not be considered to have responsibility for the inaccuracy in the U-value of the measure.

Figure 6 – Comparison of reported R-values for air layers with those expected



3 Evidence Audit

3.1 Background

An audit of 101 records of CWI installations completed after 1st June 2016 which have overwritten the default U-value with bespoke U-values was undertaken. This was to determine the extent to which the ECO2 Cavity Wall U-value Checklist was being completed correctly and whether sufficient supporting evidence was provided.

3.2 Methodology

Due to the high proportion of handwritten checklists provided for the Evidence Audit which were not suited for automated input, all data in the checklists was manually entered into a dataset. The data input was quality checked to ensure that the data had been captured accurately.

The presence of supporting calculation sheets and evidence was recorded and all supporting evidence was evaluated. Material names of each wall element were condensed into a standardised list in a similar manner to the process carried out in the Calculation Audit. U-values were compared to RdSAP defaults and thresholds based on the property's country and age band.

For each overwritten U value calculation, suppliers were required to submit for each element of the wall the details shown in the figure below:

Figure 7: Required fields from Section 1 of the ECO2 cavity wall U-value checklist

Wall Element (if any of these elements are not present at a premises please record N/A)	Description of element eg lightweight concrete block	Thickness (mm)	Lambda value selected and source eg CIBSE guide A	Supporting evidence available/justification for lambda or k value selected eg photographs, knock test, explanation of choice or if U-value is above the relevant threshold, one of the options listed in paragraph 1.2.

Based on the evidence gathered the audit looked for the following issues:

- Evidence listed on the checklist but not provided
- No evidence listed in the checklist
- Evidence provided but was insufficient
- Evidence provided that was different from the template checklist provided by Ofgem
- No sources provided for the lambda values used

An overall report of the audit's findings was created, along with reports for each supplier.

3.3 Results

Table 9 summarises the results of the Evidence Audit.

Table 9 – Summary of results of the Evidence Audit

Issue identified	Count	Percentage of audit sample
Total number of measures audited	101	100%
Checklist Missing	2	2%
Checklist completed and evidenced fully	0	0%
Checklist or evidence incomplete	99	98%
No supporting evidence listed*	14	14%
Some or all listed evidence missing*	81	80%
*Photograph**	78	
*Construction Specification**	2	
*Core Sample**	1	
*Borescope Image**	1	
Some or all listed evidence insufficient*	9	9%
No source of lambda assumption listed*	76	75%

* These groups are not mutually exclusive and so cannot be summed

3.4 Discussion of results

3.4.1 Completion of checklist

For all records the same reason was given as justification for overwriting the U-value: that the RdSAP default values assume that insulation is present when it is not. This is true up to 1976 (age band F), after which SAP assumes that improvements in the requirements and implementation of building regulations means that a larger number of cavity walls have insulation as-built.

A number of things were of note in the way that the checklists were completed.

Checklist, Section 1: Wall Element Table
Many cavity walls consist of more than one material between the internal applied finish and the inner leaf (for example: airspace & dabs, plasterboard and plaster skim), however there is limited space on the checklist to include multiple materials.

This resulted in:

- multiple materials being listed in the 'internal applied finish' row,
- multiple materials being split between 'internal applied finish' and 'other' rows,
- only one material being listed in the 'internal applied finish' row.

In the cases where only one material was listed in the 'internal applied finish' row, the wall elements on the checklist did not reflect the materials as they were listed on the calculation sheets.

Checklist, Section 1: Wall Element Table, lambda value
Whilst the wall element table asks for the source of the lambda value, very few assessors provided this; only 25 out of 101 did. This may be because they have used default values in the calculator they are using and didn't see this as a requirement, however where this is missing it has been flagged in the audit.

Checklist, Section 2: U-value Table Justification
Although justification of the finish U-value is only required in cases where the start U-value is amended and the finish U-value is not amended, a large number of records gave the same reason for the finish U-value as the start U-value being overwritten (as used in Section 1). Although this is not necessarily problematic, it indicates that there may be a lack of understanding of how this part of the checklist should be completed.

3.4.2 Evaluation of Evidence

Figure 5 summarises the frequency with which each evidence type was listed against one or more wall elements on a checklist.

Table 10: Supporting evidence listed in checklists

Listed evidence type	Frequency listed in checklists
Photograph	84
Tap / knock test	52
Construction Specification	2
Borescope	2
Core Sample	1
No evidence listed	14

Photographic evidence was listed in 84 of the 101 checklists as supporting evidence for one or more wall elements, however photographs were only provided for 9 records. Other forms of listed evidence were core samples, borescope investigation, and construction specification. This evidence was not provided. Tap/knock tests are acceptable forms of evidence and were listed on 52 checklists; however, these are done on site and could not be verified as part of this audit. No evidence was listed for any wall elements on 14 of the checklists.

The only form of evidence that was received was photographs. These were generally found to lack the detail required to determine if the listed wall element was present in the property.

Common issues included:

- That the photographs did not show evidence of all of the wall elements.
- That some material elements cannot easily be identified by photograph i.e. thickness and type of internal wall finishes.
- In the case of borescope images, that the photographs provided were of insufficient resolution to be sure that the cavity was uninsulated.
- In the case of concrete blocks, that the photographs provided were of insufficient resolution to verify the type (density) of concrete block.

In general, the photos provided were sufficient to evidence the width and type of brick and the total thickness of the wall.

3.4.3 Overwritten starting U-values

The distribution of the overwritten starting U-values in our audit sample, which replaced the RdSAP defaults, is shown in Figure 8. Each data point in the scatter plot is randomly distributed along the vertical axis to allow data points which have the same value to be clearly viewed. The U-value thresholds, used to determine whether the measure requires a higher level of justification, are also shown for the age bands of properties in the dataset (band F, G, H and I).

The graph shows a substantial grouping of the over-written U-values at these thresholds. Table 11 summarises across all age bands the proximity of the overwritten U-values to the relevant threshold for that properties age band. For our audit sample, 79% of overwritten U-values are on the threshold, or within 0.05 W/m^{2}K below the threshold.

Figure 8: Distribution of overwritten U-values against thresholds for additional evidence, evidence audit sample

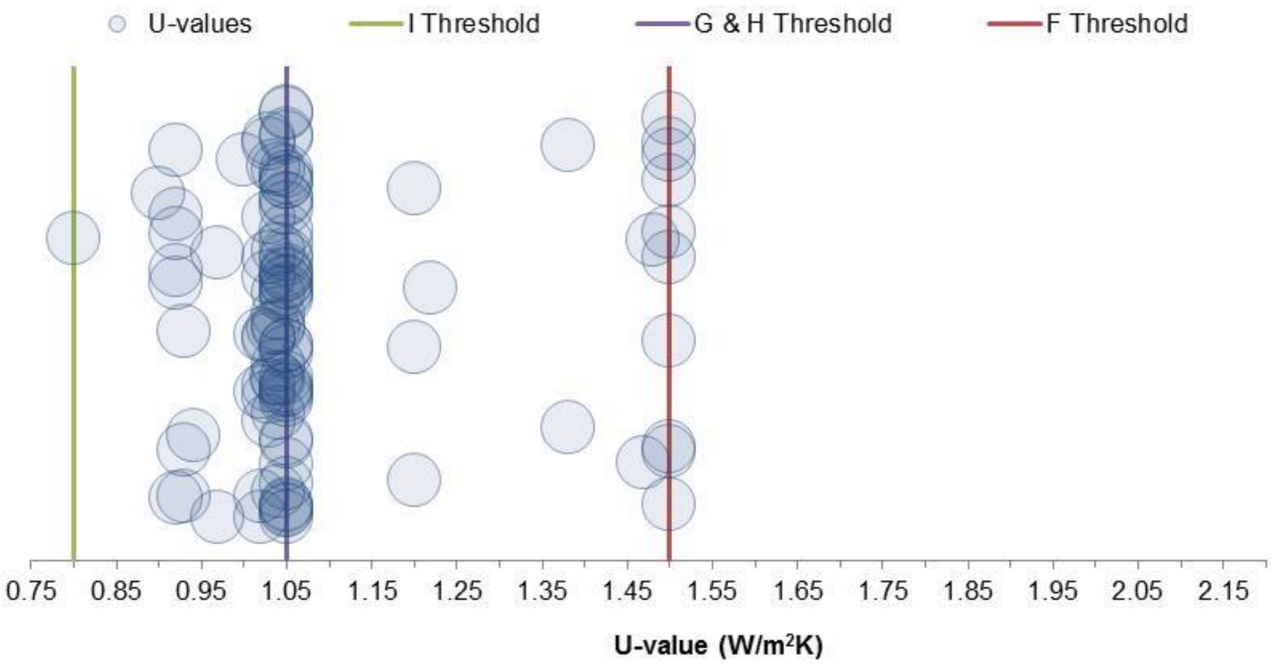
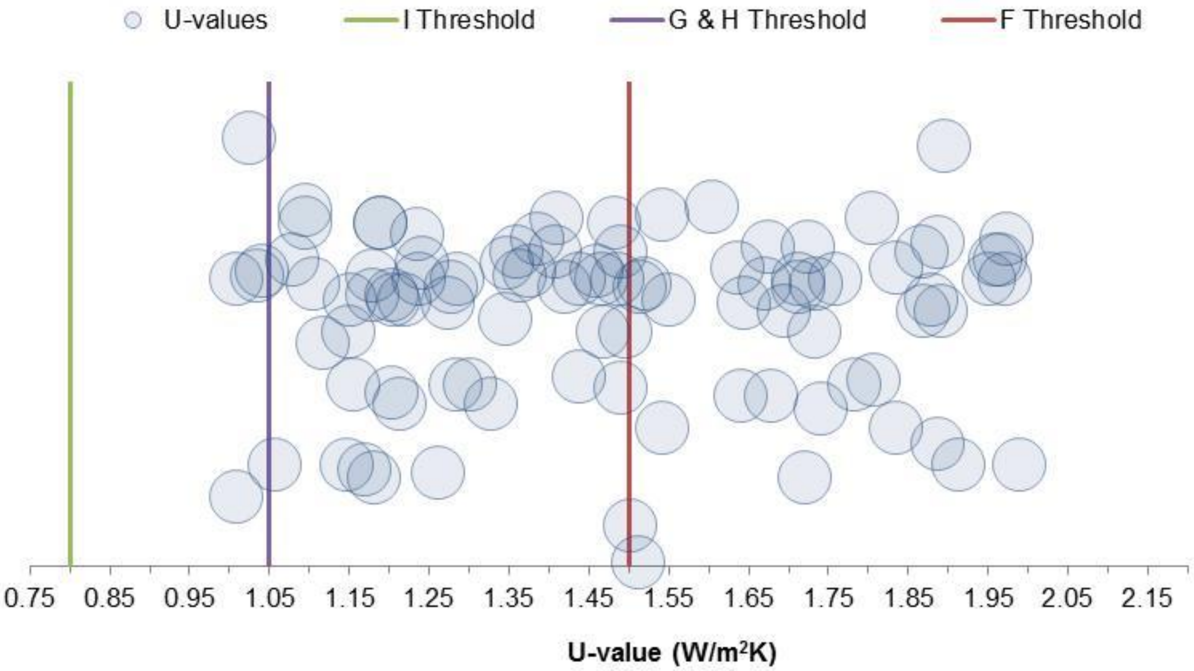


Table 11: Summary of proximity of overwritten U-values to the threshold for that age band

Relation to threshold	Count	
Records over 0.05 above threshold	6	*6%*
Records within 0.05 above threshold	0	*0%*
Records with starting U-value on threshold	52	*51%*
No of records within 0.05 below threshold	28	*28%*
No of records over 0.05 below threshold	15	*15%*

In order to investigate whether this was unusual, we randomly drew a sample of 101 measures from the calculation audit dataset for comparison; see Figure 9. Visual comparison of these two graphs shows a substantial difference in distribution. In the Evidence Audit dataset, U values are clustered on or just below the U-value thresholds set for each age band after June 2016. In the Calculation Audit sample values are more evenly distributed. This suggests that since June 2016 assessors have been inputting values into the U-value calculation sheets that result in a U-value at the maximum level that can be entered without additional, more onerous justification being required.

Figure 9: Distribution of overwritten U-values against thresholds for additional evidence, calculation audit sub-sample



As a result, the U-values in the Evidence Audit dataset are lower than those seen in the Calculation Audit dataset. This could mean that since June 2016, assessors are reporting lower U-values than in reality in order to avoid having to provide additional evidence. Or, conversely, this could mean that prior to June 2016 when more rigorous evidence was not required, assessors were not calculating U-values correctly.

The difference in the distributions between Figures 5 and 6 raises questions about the validity of both samples. It is clear from Figure 5 that there is a clear effect in the distribution caused by the set thresholds. If the U-values in the post-June 2016 evidence are being regularly manipulated to misrepresent the starting U-value reported by the supplier, then it is possible that prior to the introduction of the checklist assessors were making similar misrepresentations. However, given the evidence submitted with records prior to June 2016, an audit of this kind is unable to identify the individual cases where misrepresentations have occurred. This might be an area for further investigation beyond this audit.

4 Annex

The following graphs and tables provide some further interesting results of analysis of the Calculation Audit dataset.

Sample sizes are as follows:

Table 12: Full age band sample size

Age Band	Count of records
B	1
C	5
D	29
E	28
F	43
G	334
H	560
I	762
J	119
K	9

Table 13: Condensed age band sample size

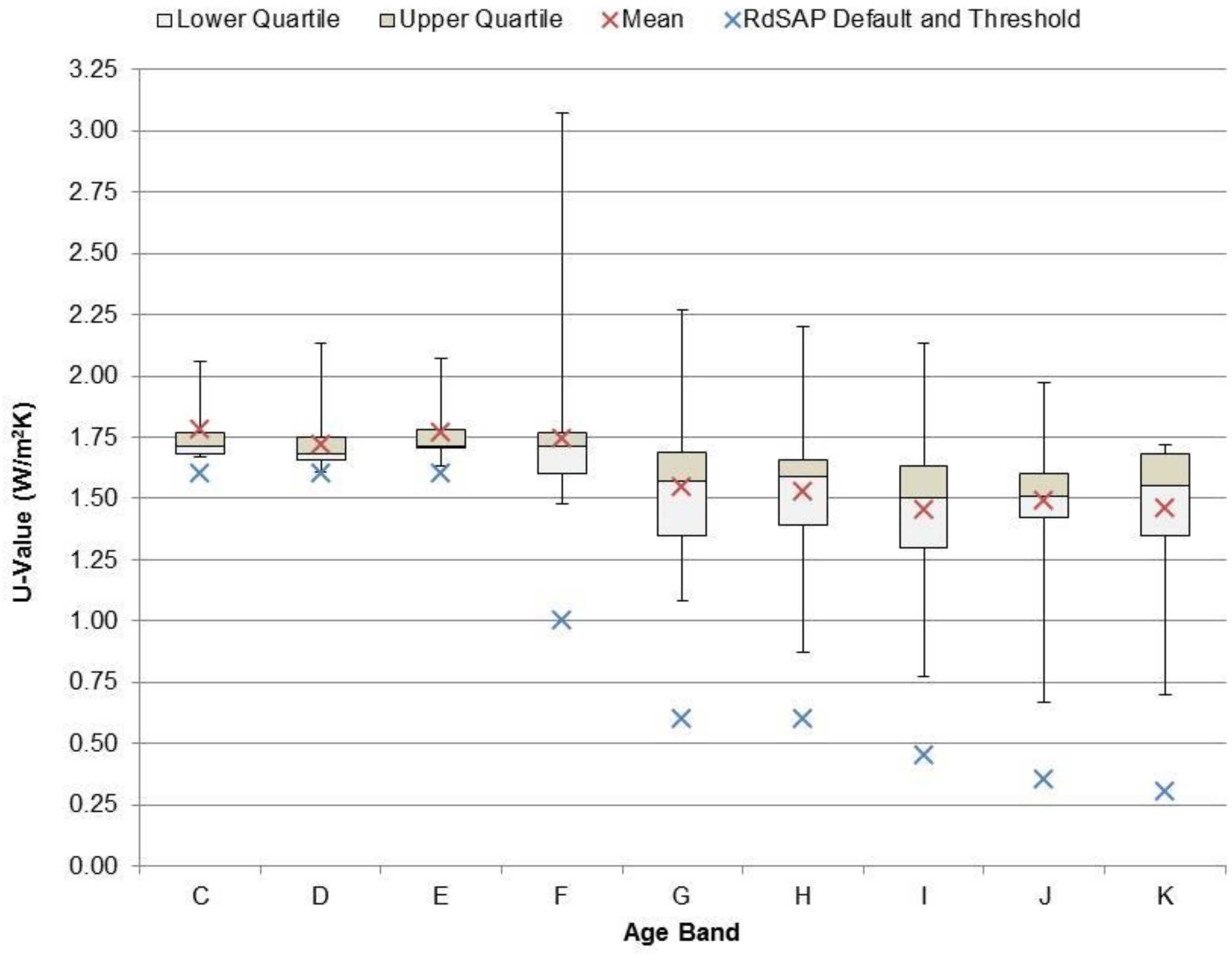
Age Band	Count of records
F and older	106
G	334
H	560
I	762
J and newer	128

4.1 U-values

U-value ranges per age band with RdSAP default and maximum threshold for overwriting U-values shown in blue.

There is a slight improvement in U-values over time especially from F to G age bands. This could be due to an increase in thin insulation which was used in some properties after 1983 (typically 10mm), and an increase in the use of plasterboard (which increased from 4% of properties in band F to 13% in band G).

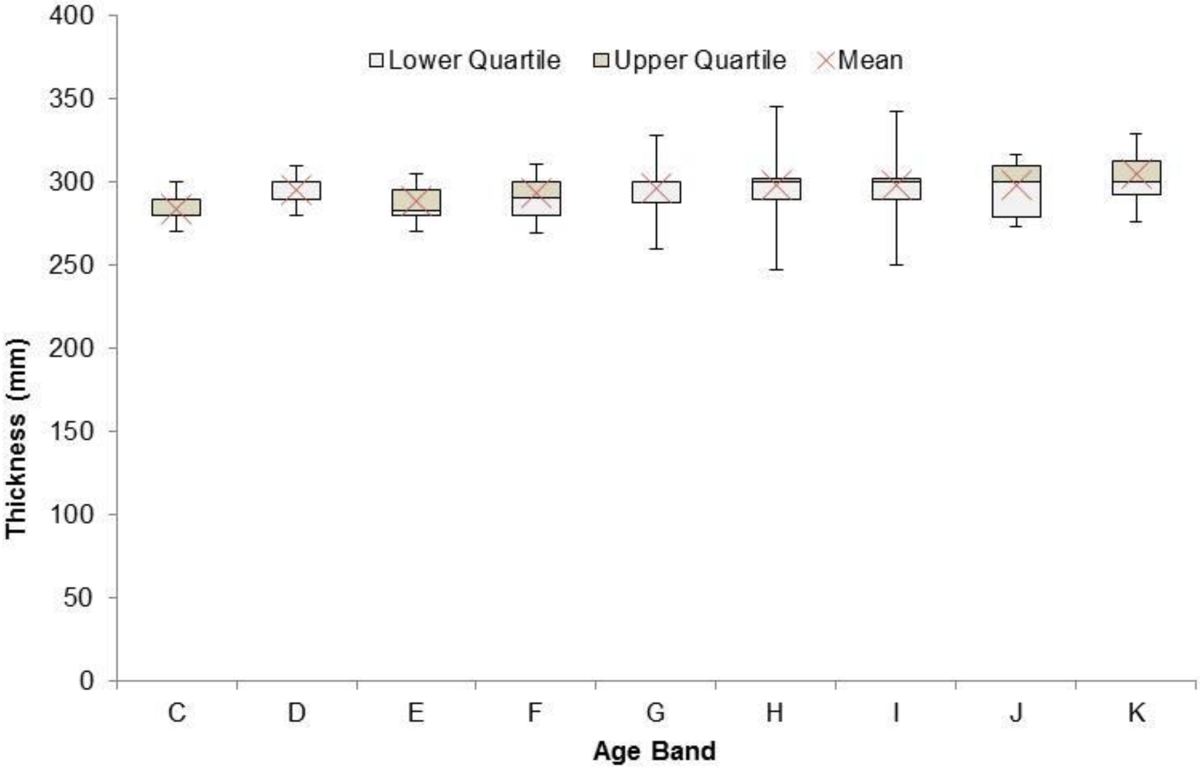
Figure 10: Distribution of U-values by age band, compared with RdSAP defaults and the thresholds used for the checklist



4.2 Wall Thickness

Wall thickness is broadly within the expected thickness range of 250mm to 300mm for cavity walls[3].

Figure 11: Distribution of wall thickness by age band



3 BEIS Standard Assessment Procedure, 2012. Table S3.

4.3 Cavity Wall Construction

Thickness and materials used in cavity wall constructions were similar across the all age bands in the dataset. Figure 12 illustrates the typical cavity wall construction showing most common materials: plaster internal finish, concrete block inner leaf, unfilled cavity and exposed brick outer leaf.

Figure 12: Typical cavity wall construction (by broad material type) by age band