BRE Client Report

Calculations of data to support ECO4 scoring methodology

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Making a positive difference
for energy consumers

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1 Introduction

The fourth iteration of the Energy Company Obligation (ECO4) is expected to use a different scoring system from ECO3 to attribute credit for installed improvement measures against obligated suppliers' targets. The 'full project scores' (FPS) for packages of improvement measures applied to homes are to be based on the improvement in the EPC rating of the dwelling as a result of the package of measures installed, as measured by before and after EPC ratings and converted to a saving in annual fuel costs.

Additionally, 'partial project scores' (PPS) will be needed to evaluate the benefits associated with individual measures for various administrative purposes. These will also be expressed as annual fuel costs savings.

For the purposes of scoring, dwellings will be assigned to a size band based on their total floor area (TFA), so that homes in larger bands (where more energy can potentially be saved) can be attributed greater credit than those in smaller bands. Four size bands have been chosen for this purpose by BEIS and Ofgem: $TFA<73m^2$, $73m^2 \leq TFA<98m^2$, $98m^2 \leq TFA<200m^2$, $200m^2 \leq TFA$.

On the basis of the overall approaches outlined above being used, BRE have undertaken some SAP modelling work on behalf of Ofgem to provide the formulae and tables needed to support the full and partial project scoring systems. This note describes the basis and assumptions used for this work.

2 Full project scoring method

A dwelling's EPC rating is produced using the SAP methodology[1], which calculates the energy requirements of the building, multiplies this by the relevant fuel prices to estimate its annual running costs, normalising by floor area, and then converts this to a rating between 1 and 100. This rating is then mapped to an A to G band according to Table 14 in the SAP specification:

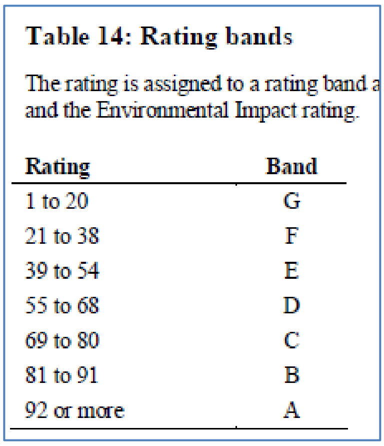

Table 14: Rating bands

The rating is assigned to a rating band a
and the Environmental Impact rating.

Rating	Band
1 to 20	G
21 to 38	F
39 to 54	E
55 to 68	D
69 to 80	C
81 to 91	B
92 or more	A

For ECO4 purposes, it has been proposed by BEIS/Ofgem to divide the bands into low and high sub-bands, using the lower and upper half of each standard band, resulting in the sub-bands in Table 1:

Table 1 – Creation of sub-bands

Band	From	Up to	Mid-point
High_A	96	100+	98
Low_A	92	96	94
High_B	86	91	88.5
Low_B	81	86	83.5
High_C	74.5	80	77.25
Low_C	69	74.5	71.75
High_D	61.5	68	64.75
Low_D	55	61.5	58.25
High_E	46.5	54	50.25
Low_E	39	46.5	42.75
High_F	29.5	38	33.75
Low_F	21	29.5	25.25
High_G	10.5	20	15.25
Low_G	1	10.5	5.75

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[1] https://www.bre.co.uk/filelibrary/SAP/2012/SAP-2012_9-92.pdf

Note that EPC ratings cannot be less than 1 (if the raw value is <1, it is reset to 1), but they can exceed 100 in rare cases.

Because a metric based on the cost per m^2 is used to generate the EPC rating, as long as the floor area is known it is possible to back-calculate the approximate running costs from an EPC rating. The proposed approach to scoring whole projects is therefore to use the EPC sub-band mid-points before and after the improvement measure, along with the average floor area for the applicable dwelling size band, to determine the improvement in SAP points and annual running costs. This can be illustrated by stepping through an example.

A. Input data

Actual floor area of dwelling = $90m^2$

EPC rating (band) before improvement package = 25 (F)

EPC rating (band) after improvement package = 65 (D)

B. Assign to ECO4 size and EPC bands

In this example the floor area falls into the $73m^2 \leq TFA < 98m^2$ band.

The ‘before’ EPC rating falls into the ‘Low_F’ band.

The ‘after’ EPC rating falls into the ‘High_D’ band.

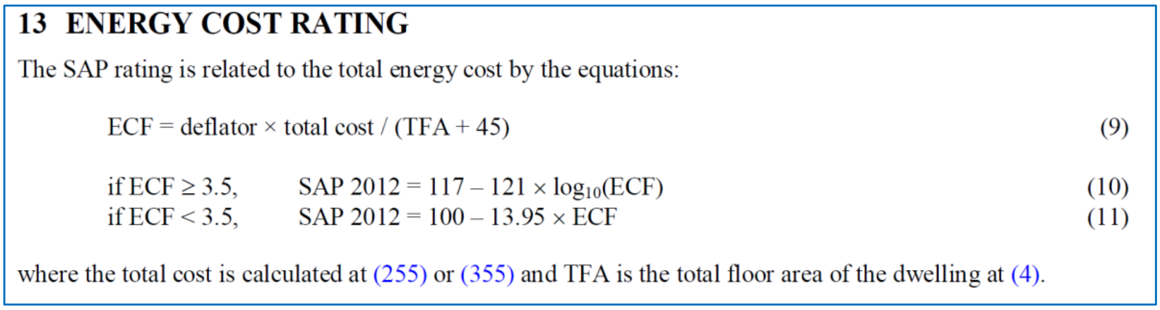
C. Assign average floor area and SAP rating for ECO4 bands

The average total floor area for a home in this floor area band, according to data from the English Housing Survey (2017-18), is $83.9m^2$. The EHS average areas for other bands are shown in Table A1 in Appendix A.

Assuming SAP ratings are evenly distributed through the bands, the mid-point can be assigned to homes falling within each band (as shown in Table 1). In the case of the Low_F band the mid-point is 25.25. In the case of the High_D band it is 64.75. The improvement in SAP points is therefore 64.75 - 25.25 = 39.5 SAP points.

D. Calculating the annual running cost saving

The SAP specification defines the procedure for calculating the SAP rating from the annual running costs using the following formulae (an extract from SAP 2012):



13 ENERGY COST RATING

The SAP rating is related to the total energy cost by the equations:

$$\text{ECF} = \text{deflator} \times \text{total cost} / (\text{TFA} + 45) \quad (9)$$

$$\text{if ECF} \geq 3.5, \quad \text{SAP 2012} = 117 - 121 \times \log_{10}(\text{ECF}) \quad (10)$$

$$\text{if ECF} < 3.5, \quad \text{SAP 2012} = 100 - 13.95 \times \text{ECF} \quad (11)$$

where the total cost is calculated at (255) or (355) and TFA is the total floor area of the dwelling at (4).

In SAP 2012 , the 'deflator' term (used to keep ratings approximately comparable from one version of SAP to the next) is 0.42.

Rearranging to make running costs the subject of the equations, the following formulae can be used to calculate the annual running costs from a SAP rating:

If SAP rating <51.175, $\text{Annual running cost} = (10^{(117 - \text{SAP rating})} / 121) / 0.42 * (\text{TFA}+45)$

Otherwise, $\text{Annual running cost} = ((100 - \text{SAP rating}) / 13.95) / 0.42 * (\text{TFA}+45)$

Applying these to the before and after mid-band SAP ratings (25.25 and 64.75) gives running costs of £1,759/yr and £775/yr, respectively. The annual saving attributed to this package of measure is therefore 1759 – 775 = £983/yr.

The proposed scoring method therefore consists of the steps and equations described above. In practice, the first 2 steps (assigning to bands) may be done by the user of the scoring tool selecting the appropriate band from a drop-down menu, rather than entering the actual floor area and SAP rating. This should reduce the chance and impact of data entry errors.

Tables illustrating the savings for all combinations of floor area band and EPC rating sub-band are shown in Appendix B. These could potentially be used as look up tables by a scoring tool or implemented directly using the formulae and tabes above.

3 Partial project scoring method

Tabulated scores (running cost savings) for individual improvement measures have been generated for each ECO4-applicable measure, for all floor area bands and each applicable[2] starting EPC sub-band. The resulting data table is too large to include in this report, containing around 9000 scores, so has been provided to Ofgem in a separate spreadsheet.

Regarding fuel prices, it was necessary to use the standard fuel prices that are used by SAP 2012 to calculate the EPC ratings for all ECO4 calculations to give consistency between partial and full project scores.

3.1 PPS for fabric improvement measures

The scores for fabric improvement measures were derived as follows:

i) An archetype dwelling from Table A1 (Appendix A) was modelled with a wide range of fabric efficiency standards and features, designed to cover the range found in the GB housing stock, described in Table A2, with and without the improvement measure applied, allowing the running cost savings to be calculated. The specific before and after values used for modelling improvement measures are described in section 3.1.1.

ii) This modelling generated multiple savings for each measure starting from a range of EPC sub-bands. The savings were averaged for all those starting in a particular sub-band to give a single figure for each sub-band.

iii) Steps i) and ii) were repeated using each of the heating system types shown in Table A3.

iv) The savings were then weighted by the heating system mix for homes in each EPC band – see Table A4. This step is significant because the heating system makes a big difference to the cost of a unit of heat and therefore to savings for fabric improvement measures, and because the heating system mix is substantially different in homes with high EPC ratings compared to those with low ones. This generally results in bigger savings for fabric improvement measures applied in homes in lower EPC bands.

v) The above steps were repeated for each of the dwelling archetypes representing the four size bands (Table A1).

vi) The resulting savings for each measure were plotted as a function of the starting SAP rating and a curve was fitted through them (see Figure 1). This was necessary because of the discontinuities in the modelled results caused by using a fixed set of fabric efficiencies to represent the continuum found in the real stock and (especially) the stepped change in heating fuel mix for each EPC band. Due to the high sensitivity of fabric savings to the heating system/fuel mix changing from one band to the next, this caused steps in the

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[2] Figures were only required up to High D for most measures. Exceptions were ‘infill measures’, which need to be available up to High B (solid wall insulation, district heating and cavity wall insulation when delivered to flats)

modelled results which would not be found if we had modelled the results for every GB home individually and averaged.

vii) The equations of the curves giving a smooth fit through the data were used to calculate the savings for each measure in each EPC starting band.

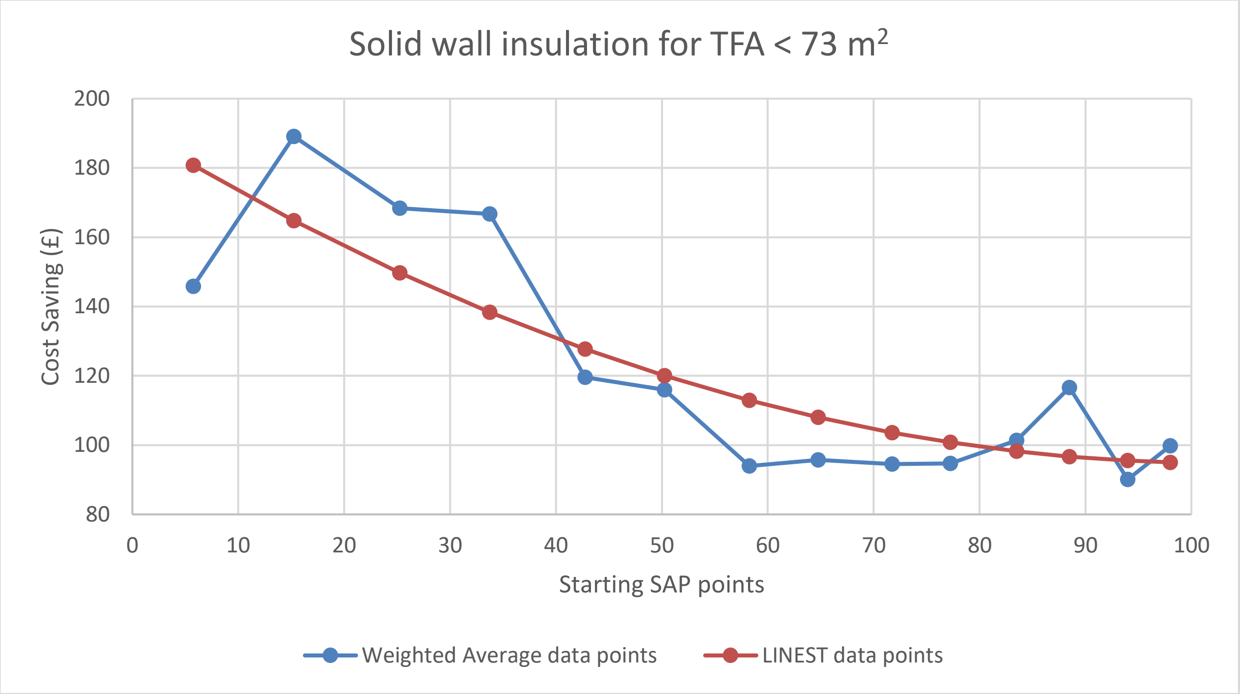

Figure 1: Example of comparison between the weighted average results and those generated from the curve fitting Excel function LINEST

To use the results of this modelling, the user could select the measure type, the starting EPC sub-band and the floor area band for the dwelling being assessed; then the scoring tool would look up the appropriate fuel cost saving from the tabulated data. This may have a reduction factor applied (see section 3.3) to give the deflated PPS. It can then be subtracted from the costs for the unimproved dwelling to give the running costs for the dwelling with the improvement applied. The post-improvement SAP rating and EPC sub-band can then be calculated using the standard SAP formulae described as part of the full project scoring method. The following example illustrates this process.

Example PPS

- Solid wall insulation is applied to a dwelling of floor area 90m² with a starting SAP rating of 25.
- The example dwelling is in the 73m²≤TFA<98m² size band and the Low_F EPC sub-band, for which a floor area of 83.9m² and a SAP rating of 25.25 are assumed. Using the reverse SAP equation described in section 1 for full project scoring, the running costs for a home of this SAP rating and floor area are calculated to be £1,759/yr.
- The pre-calculated running cost saving for the Low_F starting band for this measure is taken from the PPS table, giving a saving of £423/yr. This is multiplied by the reduction factor of, say, 0.75, giving a net PPS of £317/yr. Subtracting this from the running costs for the unimproved dwelling gives a post-improvement running cost of £1,441/yr. Using the standard SAP equations,

this is converted to a SAP rating of 35.70, which falls into the High_F sub-band, giving a SAP point saving of 10.45.

3.1.1 ‘Before’ and ‘after’ values assumed for fabric measure savings

This section presents the ‘before’ and ‘after’ values for specific installations of measures used in the calculation of the PPS.

3.1.1.1 Solid wall insulation

Savings were calculated for the improvements in U-value indicated in Table 2. These savings may be applied to internal, external or hybrid wall insulation on either solid or cavity walls. The before and after U-values are taken from Section S5.1 of RdSAP (SAP 2012 v9.94[3]) which assume a typical insulation material.

Table 2: Assumed U-values for solid wall insulation

	Added Insulation thickness			**To defined U-value**	
	50mm	**100mm**	**150mm**	**0.3 W/m2K**	**0.6 W/m2K**
Starting U-value (W/m^2K)	**End U-values (W/m^2K)**				
2.0	0.60	0.35	0.25	0.3	0.6
1.7	0.55	-	0.23	0.3	0.6
1.0	0.45	-	-	0.3	0.6
0.6	-	0.24	-	0.3	-
0.45	-	0.21	-	-	-

3.1.1.2 Cavity wall insulation

Savings were calculated for three construction age bands using standard a U-value calculation methodology applied to the relevant construction (e.g. brick/brick, brick/block with an average cavity width derived by BRE from installer data, as used for the CERT scheme). These age bands are associated with significant changes in wall U-values due to the introduction of successive new Building Regulations, and are not based on RdSAP assumptions for cavity walls. For cavity wall insulation with a standard thermal conductivity of 0.040 W/mK the U-values are as shown in Table 3.

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[3] https://www.bregroup.com/wp-content/uploads/2019/09/RdSAP_2012_9.94-20-09-2019.pdf

Table 3: Assumed base U-values for cavity wall dwellings as used in the calculation of CWI savings

Year of construction	Uninsulated U-value (W/m^{2}K)	Insulated U-value (W/m^{2}K)	Weighting
(1) Pre 1976	1.435	0.478	73%
(2) 1976 - 83	1.003	0.417	13%
(3) post 1983	0.694	0.343	15%

The U-values for the three age bands are combined to give one uninsulated and one insulated U-value regardless of the age band of the wall. This is consistent with latest research which shows wide variation in measured U-values for each age band. The three values are averaged using the weightings in the table, which are derived from the number of uninsulated cavity wall dwellings for each age band in the national stock.

The method is then repeated using cavity wall insulation with a thermal conductivity of 0.033 W/mK and 0.027 W/mK. This results in the U-values in Table 8 below for all three cavity wall insulation deemed score variants. The resulting U-values after weighting by age band are also given in Table 4.

Table 4: U-values for Cavity Wall Insulation

Thermal conductivity (W/mK)	Weighted average 'before' U-value (W/m^{2}K)	Weighted average 'after' U-value (W/m^{2}K)
0.040	1.272	0.451
0.033	1.272	0.393
0.027	1.272	0.338

A partial fill measure was also modelled with a before U-value 0.45 and an after U-value of 0.28.

Party cavity wall insulation savings were calculated using the standard RdSAP U-values. The U-value assumptions are shown in Table 5 below.

Table 5: U-values for Cavity Wall Insulation of party walls

	'before' U-value (W/m^{2}K)	'after' U-value (W/m^{2}K)
Party wall insulation	0.5	0.2

Note that flats and maisonettes are assumed to be constructed in such a way as to avoid a thermal bypass. Therefore, there are no scores for party cavity wall insulation for these property types.

3.1.1.3 Loft insulation

During the earlier CERT scheme, a case was made that during 'top-up' of loft insulation, the additional savings from correction of the existing insulation was not taken account of. A survey of 200 lofts was commissioned, collecting data on 'disturbances' such as missing or compressed insulation, and also the fraction of wood (the joists), area of loft hatches and water tanks. From this data, modified U-values were derived, resulting in an increase to the scores. These deemed scores are calculated using these modified U-values to take account of these additional savings, resulting in improved scores.

The starting U-values were determined from examination of English Housing Survey data, and assessment of the effect on the final U-value. This is shown in Figure 2 and Figure 3 below.

Figures 2 and 3 show:

a) the reduction in savings with existing depth of insulation. This graph indicates very little increase in savings when insulating from a depth above about 125mm,

b) the percentage of homes with different existing depths. This indicates a significant number with 100mm. This is a common depth, being the normal depth of joists, and so usually the maximum level while still allowing storage on the joists without compressing the insulation.

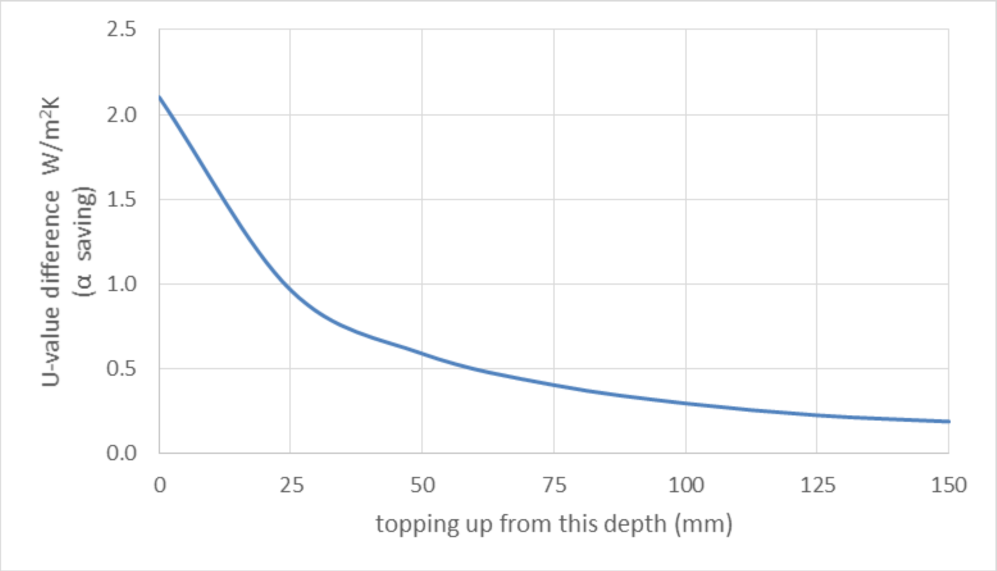

Figure 2: Difference in loft insulation U-value from topping up from different depths.

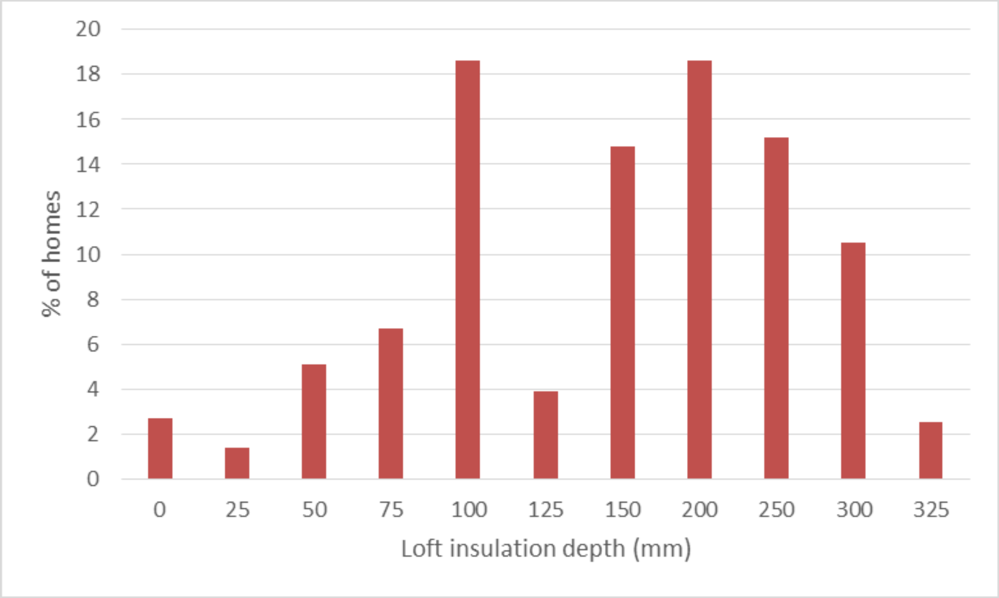

Figure 3: Distribution of loft insulation depths within England.

On the basis of this data, a weighted average U-value of depths in the stock of 100mm or less, and of 125mm to 200mm, were chosen as the 'before' cases (EHS data was recorded in 25mm intervals, any depths between were rounded). The post-insulation U-value assumes a thickness of 270mm, which reflects the requirements of Building Regulations. Table 6 shows the U-values used in the calculations.

Table 6: U-values for loft insulation measure variants

	U-value before (W/m²K)	U-value after (W/m²K)
100mm or less of existing insulation	0.727	0.185
125mm or more of existing insulation	0.317	0.185

3.1.1.4 Room-in-roof insulation

For the ECO3 Deemed Scores, a review of 'room in the roof' (RiR) base assumptions was made. This review considered the different sizes of RiRs, and the base U-values of RiRs. The same assumption was made for ECO4, but the basis is repeated here for completeness.

The size of a RiR is constrained by the roof sloping on two, three or four sides. In order to calculate the size of each of the elements of a RiR, RdSAP requires the room floor area (as a minimum) to be measured, and a formula is applied based on this to estimate the areas of the other elements. However, measurement of the floor area is not considered suitable for deemed scores in ECO, and EHS and other data does not directly record the floor area of RiRs (only their presence and some information on their type and age). Instead, data on the *type* of RiR, which is collected by the EHS, is used in order to estimate floor area.

Analysis of EHS data identified two different types of RiR:

a) Those with no dormer windows (e.g. 'Velux' type conversions), or with small 'standard' dormer windows
b) Those with large 'Roof Extension' or 'Box Dormers'. Typically these would be at the rear of the property only, but in some cases they would also extend to the front elevation

It is then assumed that RiRs of type a) typically have a floor area of 50% of the floor below. Those of type b) are split into two categories, depending on whether there is a roof extension or box dormer on one or two elevations. RiRs with either of these elements on one elevation are assumed to have a floor area of 75% of the floor area below. RiRs with these on two elevations, are assumed to have a floor area of 95%.

Using these assumptions, and considering only RiRs built before 2002 (after this date, the performance of elements of the RiR are assumed to be equal to or better than an improved RiR), we can produce an estimate of the floor area of all RiRs using the EHS data on the distribution of these types of RiR in the stock as shown in Table 7. This produces an average floor area for RiRs of 59% of the area of the floor below.

Table 7: Assumptions used in estimating size of rooms-in-roof.

Dormer type of room-in-roof	**Distribution of room-in-roof type in housing stock (EHS data – pre-2002 room-in-roofs only)**	**Assumed proportion of floor area occupied by room-in-roof**
No dormer or standard dormer	70%	50%
Front or back roof extension dormer	21%	75%
Front and back roof extension dormer	9%	95%
All pre-2002 room-in-roofs	100%	**Weighted average = 59%**

This value is used to calculate a RiR floor area for each dwelling archetype, which was then used within the RdSAP calculations to produce the areas of each of the RiR heat loss elements (RiR walls & roof).

EHS data on ages can also be used to assign U-values to these elements. The EHS collects data on the age of properties for 'as-built' RiRs, and an estimated age of loft conversions for converted RiRs. These two pieces of information are combined to produce the age of a RiR, which can then be matched with the corresponding U-value for each element from the RdSAP table. A weighted average U-value, representative of RiRs built before 2002, is then produced using the EHS data on the distribution of RiRs in each age band. The results of this analysis are shown in Table 8 below.

Table 8: U-values for loft insulation

Age of room in roof	Total number of dwellings	U-value of elements (using RdSAP Table S10)
Pre 1966	1,068,000	2.30
	47.0%	
1967 - 1975	233,000	1.50
	10.3%	
1976 - 1982	160,000	0.80
	7.0%	
1983 - 1990	274,000	0.50
	12.1%	
1991 - 1995	214,000	0.35
	9.4%	
1996 - 2002	324,000	0.35
	14.3%	
All dwellings with RIR	2,273,000	**Weighted average 1.43**
	100.0%[4]	

Based on this analysis, the scores for RiR insulation have been produced using the U-values shown in Table 9 below. The 'after' U-values are based on Building Regulations PartL1B Table 3, assuming an insulation depth of 270mm at loft and ceiling (modified to allow for the 'disturbances' as described under 'Loft insulation').

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[4] This total percentage allows for a 0.01% error due to rounding

Table 9: U-values for Room in Roof insulation.

	U-value (W/m^2K)	
	before	after
Ceiling	1.43	0.185
Walls	1.43	0.3
Residual	0.36	0.36

3.1.1.5 Flat roof insulation

Savings were calculated using the standard SAP U-value for an uninsulated roof and insulating to Building Regulations Approved Document Part L1B Table 3 requirements. The U-values used for flat roof insulation are shown in Table 10 below.

Table 10: U-values for flat roof insulation.

U-value before (W/m^2K)	U-value after (W/m^2K)
2.3	0.18

3.1.1.6 Pitched roof insulation

In the absence of specific data, the U-value achieved by pitched roof insulation was assumed to be the same as for loft insulation, being improved in both cases to a U-value of 0.185. This was based on starting U-values of 2 (for no previous insulation being present) and 1 (where there is some existing insulation present). However, to allow for the larger heat loss area of roofs insulated at rafter level compared to joist level, the horizontal roof area (before and after improvement) was multiplied by 1 / cos 40° = 1.3.

3.1.1.7 Underfloor insulation

Savings were calculated for insulating a suspended wooded floor using the U-values shown in Table 11 below. The 'before' U-value for each of the dwelling types/sizes was derived from a standard calculation for wooden timber ground floors (derived from the floor area and perimeter of external walls). For the 'after' case the Building Regulations Part L1B Table 3 requirement of 0.25 W/m^2K was used.

Table 11: U-values for floor insulation.

U-value before (W/m^2K)	U-value after (W/m^2K)
Suspended wooden floor U-value calculation (depends on the area and perimeter so is a different value for each dwelling type and size, varying from 0.46 to 0.66 W/m^2K for a suspended timber floor)	0.25
Solid floor U-value calculation (depends on the area and perimeter so is a different value for each dwelling type and size, varying from 0.48 to 0.67 W/m^2K for a suspended timber floor)	0.25

3.1.1.8 Draught-proofing

Savings were calculated using a 'before' case of 0%, and an 'after' case of 100% draught-proofing.

3.1.1.9 Glazing

Savings from glazing were calculated for upgrading windows to a U-value of 1.6 W/m^{2}K (the standard required in Building Regulations Approved Document Part L1B Table 1), from two base cases:

(a) Single glazed windows
(b) Double glazed windows, typical for the existing stock as defined in 'base cases' (table 2 in section 2.2).

The U-values used in these calculations are shown in Table 12 below.

Table 12: U-values for glazing upgrades

Before	after
Single glazing U-value: 4.8 W/m^{2}K 0% draughtsealing	Double or triple glazing U-value: 1.6 W/m^{2}K 100% draughtsealing
Double glazing U-value: 2.2 W/m^{2}K 100% draughtsealing	Double or triple glazing U-value: 1.6 W/m^{2}K 100% draughtsealing

3.1.1.10 High performing doors

Savings from high performing doors were calculated for improving the doors from a standard U-value as given in RdSAP for pre-1976 age bands, to that required by the Building Regulations Approved Document Part L during a refurbishment. This can be applied to doors with areas of glazing since the same Part L minimum requirements apply (n.b. the ECO2t measures table distinguishes between doors with less than 60% and greater than 60% glazing, which give the same savings, but with different lifetimes). The U-value assumptions are shown in Table 13 below.

Table 13: U-values for door improvements

U-value before (W/m^{2}K)	U-value after (W/m^{2}K)
3.0	1.8

3.1.1.11 Park home insulation

Although many sizes of Park Homes may be found, two common types are found which can be described as either "single" or "double" types. Both are typically 12 metres long and either 3 or 6 metres wide. Savings have been calculated for these two sizes as shown below in Table 14:

Table 14: Park Home dimensions

	Size	Floor area (m^2)
Park Homes	single	36
	double	72

Developing 'before' U-values for park home insulation measures required a different methodology than for other measures, as there is limited data available to come to a 'typical' park home. Combining data from the relevant British Standard for park homes (BS3632 Residential park homes – Specification), the RdSAP age bands and various studies and investigations of park homes suggest the 'before' U-values outlined in Table 15 are a reasonable approximation of a typical park home.

The ‘after’ position assumes an upgrade to add a thermal resistance of 0.695, a level which internal BRE work considers to be achievable, and which also brings the elemental U-values of the Park Home up to approximately the level of the BS3632:1995 standard. The floor U-values are dependent on whether the single or double park home is selected.

Table 15: U-values used for Park Home Insulation measures

	U-value before (W/m²K)	U-value after (W/m²K)
Roof	0.6	0.42
Wall	1.2	0.65
Floor	0.73 (double)/0.92 (single)	0.52

3.1.2 Photovoltaics

Although not a fabric improvement measure, PV savings were calcaulted in the same manner as the figures for fabric measures. Savings were derived using the configuration defined in SAP Appendix T ‘Improvement measures for Energy Performance Certificates’. This identifies a solar panel as 2.5kWp, and located on a south facing roof on an incline of 30°, with modest overshading. Scores for specific areas of PV may be calculated by adjusting these values proportionately using the kWp of the individual installation.

3.2 PPS for heating system upgrades

The PPS for heating systems were calculated using a different method which is based on the fact that it is possible to calculate a ‘cost of heat’ for any heating system and use this to infer the dwelling’s heat demand from the EPC rating and floor area. The following illustrative example demonstrates this process.

- A home of 90m² in EPC sub-band low-E is heated by an old gas boiler of 60% efficiency.
- The reverse SAP rating formula from section 1 can be used to calculate the approximate running costs of the dwelling from its EPC rating, in this case £1,759/yr. Subtracting the proportion of this cost which is for lighting, pumps and fans, and standing charges leaves £1,553/yr, which is the proportion used for space and water heating, provided by the boiler.
- In SAP 2012, the cost of gas is 3.48p per kWh, so the cost of heat would be 3.48 / 60% = 5.8p/kWh. Therefore, the heat requirement (for space and water heating) of this home must be £1,553 / (5.8 / 100) = 26,776 kWh/yr.
- If the boiler is replaced by a new 90% efficient gas condensing boiler, the new cost of heat would be 3.48 / 90% = 3.87p/kWh.
- The cost of providing the same amount of heat would then be 26,776 x (3.87 / 100) = £1,036/yr. Adding back on the same amounts for other uses and the standing charge gives total costs of £1,242/yr. Thus, the saving for the improvement measure can be calculated as 1,759 – 1,242 = £517/yr. The improved EPC rating can then be calculated from the running costs, if needed.

Using this process, and the assumptions about the cost of heat described in Table 16, the savings for going from and to all combinations of heating systems in ECO4 were calculated for each floor area band and each starting EPC sub-band.

Table 16 – Key heating system assumptions

Heating type	Cost of fuel (p/kWh)	Efficiency	Cost of heat (p/kWh)
Mains gas condensing boiler	3.48	88%	3.95
Mains gas non-condensing boiler	3.48	75%	4.64
Mains gas Back Boiler to radiators	3.48	66%	5.27
Mains gas fire with back boiler	3.48	50%	6.96
Mains gas room heaters	3.48	60%	5.80
LPG condensing boiler	7.6	88%	8.64
LPG non-condensing boiler	7.6	75%	10.13
Bottled LPG boiler	10.3	81%	12.72
LPG room heaters	10.3	60%	17.17
Condensing oil boiler	5.44	90%	6.04
Non-condensing oil boiler	5.44	80%	6.80
Biomass Boiler	3.07	65%	4.72
Soild fuel boiler	3.67	60%	6.12
Solid fuel room heaters	3.67	50%	7.34
Electric room heaters	13.19	100%	13.19
Electric storage heaters	5.5	85%	6.47
Electric boiler	13.19	100%	13.19
High Heat Retention Storage Heaters	5.5	95%	5.79
District heating system (non-CHP)	4.24	100%	4.24
District heating system (CHP)	2.97	100%	2.97
Ground source heat pump	13.19	285%	4.63
Air source heat pump	13.19	251%	5.25
mCHP(TFA<73)	3.48	42%	1.07
mCHP(73≤TFA<98)	3.48	48%	1.48
mCHP(98≤TFA<200)	3.48	49%	1.99
mCHP(200≤TFA)	3.48	54%	2.99

In the case of storage heaters, an efficiency of <100% is used in Table 16 (despite their true efficiency of heat generation being 100%) to allow for their lower responsiveness compared to direct heating systems, which results in a higher heat demand.

In the case of micro CHP, which generates electricity as well as heat, the cost of heat figure in Table 16 accounts for the value of the electricity generated, as well as the cost of the fuel used – hence the cost of heat is lower than the cost of the gas used to generate it.

This approach requires the heating type before the improvement to be known (in contrast to the PPS for fabric measures which are averaged over all heating systems). The user of the scoring tool would therefore need to select the floor area band, the initial EPC rating sub-band and the initial heating system type to get the saving for a heating upgrade. This approach was taken because the savings from a heating upgrade are predominantly determined by what system was present before the upgrade.

The fuel costs needed for this approach were taken directly from SAP 2012 Table 12, unmodified, to give consistency with the FPS.

3.3 Reduction factor

A reduction factor is can be applied to individual improvement measure scores to reduce the possibility of more credit being given for the installation of an individual measure than it would receive when part of a package of measures. This can occur because the interaction between measures is not included when scoring measures in isolation. For example, when a heating upgrade and an insulation upgrade are installed together the sum of their individually calculated savings will be less than their combined saving because installing insulation reduces the heating demand, so the saving achieved by the heating system falls; or, conversely, the saving for installing insulation is reduced when the heating system is more efficient. In practice the reduction caused by this interaction will vary with the measures being combined and the initial condition of the dwelling, but to keep things simple the use of a global reduction factor has been proposed. A set of illustrative examples for a few scenarios is shown in Appendix C, suggesting a factor of around 0.75, however a more detailed analysis considering the interaction for all possible combinations of measures will be used to determine the final reduction factor to be used.

In most cases, the PPS will be discarded for scoring purposes and the FPS method described in section 1 used instead, meaning the interaction between measures would be handled properly without the need for a correction factor. The correction factor would just be applied to PPS to avoid creating undue optimism when the impact of an individual measure is needed.

3.4 Scoring innovative measures

The scoring approach for innovative measures can be treated in a similar way to PPS, following the process described above to score an individual measure. Innovative measures can then be added to the PPS lookup tables as needed.

The notable difference in scoring innovatiove measures is that they are usually cannot be modelled using SAP, so in most cases the prior (and major) task needed to score them would be the creation of an evidence-based calculation methodology to establish running cost savings for a dwelling in each size band and each EPC sub-band. It may also be appropriate to apply a reduction factor relating to the uncertainty of the efficacy of the measure (e.g. based on the quality of evidence for the saving).

3.5 Proxy heating types

For ECO3, the savings for all measures depended on the heating system present prior to the improvement being made. To avoid the table of scores becoming unmanageably large, instead of providing scores for homes with rare heating systems, a proxy was assigned (e.g. homes with electric ceiling heaters would be assigned the savings calculated for homes with direct electric room heaters) on the basis of giving the closest match, taking account of the efficiency, fuel cost and responsiveness of the system.

For ECO4, PPS for fabric improvement measures are calculated as a weighted average over all heating systems types, so proxy heating types are not needed; but for heating measures the initial heating system type is still needed and therefore proxy heating types will be needed where rare heating systems are present, prior to improvement.

By calcaulting a typical cost of heat figure for each system type and comparing to the main heating types for which we do have PPS listed in Table 16, the closest match has been chosen as the proxy system of the same broad type (central heating or room heaters). These proxy systems are shown in Table 17.

Table 17: Proxy heating systems to be used for rare heating types

Type	Rare heating types	Cost of fuel (p/kWh)	Efficiency	Cost of heat (p/kWh)	Proxy
CH	Air-oil hybrid heat pump	13.19	251%	5.25	Air source heat pump
CH	Biomass/wood central heating	5.26	60%	8.77	LPG condensing boiler
RH	Biomass/wood room heating	4.61	50%	9.22	Solid fuel room heaters
CH	Bottled LPG back boiler to radiators	10.3	66%	15.61	Electric boiler
CH	Bottled LPG central heating	10.3	81%	12.72	Bottled LPG boiler
RH	Bottled LPG fire with back boiler	10.3	50%	20.60	LPG room heaters
CH	Bottled LPG range cooker boiler	10.3	61%	16.89	Electric boiler
RH	Bottled LPG room heaters	10.3	60%	17.17	LPG room heaters
RH	Electric ceiling heaters	13.19	100%	13.19	Electric room heaters
RH	Electric underfloor heaters	13.19	95%	13.88	Electric room heaters
CH	Electric warm air system	13.19	100%	13.19	Electric boiler
CH	Gas back boiler to radiators	3.48	66%	5.27	Mains gas Back Boiler to radiators
CH	Gas fire with back boiler	3.48	50%	6.96	Non-condensing oil boiler
CH	Gas range cooker boiler	3.48	61%	5.70	Condensing oil boiler
CH	Gas warm air system	3.48	70%	4.97	Biomass Boiler
CH	LPG back boiler to radiators	7.6	66%	11.52	Bottled LPG boiler
CH	LPG boiler - Special Condition 18*	3.48	81%	4.30	District heating system (non-CHP)
CH	LPG fire with back boiler	7.6	50%	15.20	Electric boiler
CH	LPG range cooker boiler	7.6	61%	12.46	Bottled LPG boiler
CH	LPG warm air system	7.6	70%	10.86	LPG non-condensing boiler
RH	No heating present	13.19	100%	13.19	Electric room heaters
CH	Oil range cooker boiler	5.44	71%	7.66	LPG condensing boiler
RH	Oil room heaters	5.44	55%	9.89	Solid fuel room heaters
CH	Oil warm air system	5.44	70%	7.77	LPG condensing boiler
CH	Solid fossil fuel back boiler to radiators	4.61	63%	7.32	Non-condensing oil boiler
RH	Solid fossil fuel fire with back boiler	4.61	50%	9.22	Solid fuel room heaters

Appendix A Modelling inputs

Dwelling Archetype	Band	Average Area (m2)
Small 2 ext. Wall Flat	TFA < 73	56.1
Medium Semi-detached 3	73 ≤ TFA < 98	83.9
Medium Semi-detached 4	98 ≤ TFA < 200	127.6
Large Detached	200 ≤ TFA	266.6

***Table A1**: Dwelling types and areas*

Roof U-value	Wall U-value	Window U-value	Floor U-value	PV fraction of main roof
0.10	0.10	0.75	0.10	0.30
0.13	0.20	1.50	0.25	0.28
0.30	0.50	1.60	0.50	0.20
0.59	0.71	2.09	0.57	0.18
0.87	0.93	2.57	0.64	0.13
1.16	1.14	3.06	0.71	0.10
1.44	1.36	3.54	0.79	0.05
1.73	1.57	4.03	0.86	0.03
2.01	1.79	4.51	0.93	0.00
2.30	2.00	5.00	1.00	0.00

***Table A2**: Range of fabric and PV inputs*

Heating System	Efficiency	Responsivness
Electric storage heater	100%	0.2
LPG boiler non-condensing	75%	1
Electric room heaters	100%	1
Gas boiler 75	75%	1
Gas boiler 88	88%	1
Oil boiler condensing	90%	1
LPG boiler condensing	88%	1
Oil boiler non-condensing	80%	1
Gas fire with back boiler	50%	1
High heat retention storage heater	100%	0.8

***Table A3**: Range of heating systems modelled with the various fabric upgrade measures*

Proportion of heating systems by EPC band							
	EPC band						
Main heating system	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Mains gas condensing boiler	77.4%	77.4%	82.0%	66.2%	29.2%	2.3%	0.0%
Mains gas non-condensing boiler	0.0%	0.0%	6.4%	18.1%	30.5%	2.7%	0.0%
Gas fire with back boiler	0.0%	0.0%	0.0%	1.0%	2.0%	5.0%	1.0%
Oil condensing boiler	0.6%	0.6%	0.4%	1.4%	5.1%	7.1%	1.1%
Oil non-condensing boiler	0.0%	0.0%	0.0%	1.0%	6.9%	15.7%	5.5%
LPG condensing boiler	0.0%	0.0%	1.0%	5.0%	7.0%	8.0%	8.9%
LPG non-condensing boiler	0.0%	0.0%	0.0%	1.0%	2.0%	9.0%	8.4%
Electric storage heaters	0.0%	2.7%	3.2%	2.2%	8.6%	18.0%	11.1%
Direct electric heaters	0.0%	0.0%	1.0%	1.0%	3.2%	20.1%	42.5%
HHR electric storage heaters	10.7%	8.0%	2.0%	1.0%	0.0%	0.0%	0.0%
Other	11.3%	11.3%	4.0%	2.1%	5.5%	12.1%	21.5%
TOTAL	100%	100%	100%	100%	100%	100%	100%

***Table A4**: Mix of heating systems for homes in each starting EPC band, based on EHS 2017-18 data. Green rows required further assumptions to estimate their proportion. ‘Other’ was pro-rated into previous categories for the final weighting.*

Appendix B Full project savings (£/yr) for all size and rating bands

TFA<73												
Starting EPC band ˅	Finishing EPC band											
	Low_A	High_B	Low_B	High_C	Low_C	High_D	Low_D	High_E	Low_E	High_F	Low_F	High_G
High_B	95	0	0	0	0	0	0	0	0	0	0	0
Low_B	181	86	0	0	0	0	0	0	0	0	0	0
High_C	289	194	108	0	0	0	0	0	0	0	0	0
Low_C	384	289	203	95	0	0	0	0	0	0	0	0
High_D	505	410	324	216	121	0	0	0	0	0	0	0
Low_D	617	522	436	328	233	112	0	0	0	0	0	0
High_E	754	659	573	465	370	249	137	0	0	0	0	0
Low_E	886	791	704	596	502	381	269	132	0	0	0	0
High_F	1070	975	889	781	686	565	453	316	185	0	0	0
Low_F	1276	1181	1095	987	892	772	659	522	391	206	0	0
High_G	1566	1471	1384	1277	1182	1061	949	812	680	495	289	0
Low_G	1896	1801	1715	1607	1512	1392	1279	1142	1011	826	620	331

73≤TFA<98												
Starting EPC band ˅	Finishing EPC band											
	Low_A	High_B	Low_B	High_C	Low_C	High_D	Low_D	High_E	Low_E	High_F	Low_F	High_G
High_B	121	0	0	0	0	0	0	0	0	0	0	0
Low_B	231	110	0	0	0	0	0	0	0	0	0	0
High_C	368	247	137	0	0	0	0	0	0	0	0	0
Low_C	489	368	258	121	0	0	0	0	0	0	0	0
High_D	643	522	412	275	154	0	0	0	0	0	0	0
Low_D	786	665	555	418	297	143	0	0	0	0	0	0
High_E	961	840	730	592	471	317	175	0	0	0	0	0
Low_E	1128	1007	898	760	639	485	342	168	0	0	0	0
High_F	1364	1243	1133	996	875	721	578	403	235	0	0	0
Low_F	1627	1506	1396	1258	1137	983	840	666	498	263	0	0
High_G	1995	1874	1764	1627	1506	1352	1209	1034	867	631	369	0
Low_G	2417	2296	2186	2048	1927	1773	1630	1456	1288	1053	790	421

98≤TFA<200												
Starting EPC band ˅	Finishing EPC band											
	Low_A	High_B	Low_B	High_C	Low_C	High_D	Low_D	High_E	Low_E	High_F	Low_F	High_G
High_B	162	0	0	0	0	0	0	0	0	0	0	0
Low_B	309	147	0	0	0	0	0	0	0	0	0	0
High_C	493	331	184	0	0	0	0	0	0	0	0	0
Low_C	655	493	346	162	0	0	0	0	0	0	0	0
High_D	862	700	552	368	206	0	0	0	0	0	0	0
Low_D	1053	891	744	560	398	191	0	0	0	0	0	0
High_E	1287	1125	977	793	631	425	234	0	0	0	0	0
Low_E	1511	1349	1202	1018	856	650	458	225	0	0	0	0
High_F	1827	1665	1517	1333	1171	965	774	540	315	0	0	0
Low_F	2178	2016	1869	1685	1523	1317	1125	892	667	352	0	0
High_G	2672	2510	2363	2179	2017	1810	1619	1385	1161	845	494	0
Low_G	3236	3074	2927	2743	2581	2375	2183	1950	1725	1410	1058	564

200≤TFA												
Starting EPC band ˅	Finishing EPC band											
	Low_A	High_B	Low_B	High_C	Low_C	High_D	Low_D	High_E	Low_E	High_F	Low_F	High_G
High_B	293	0	0	0	0	0	0	0	0	0	0	0
Low_B	558	266	0	0	0	0	0	0	0	0	0	0
High_C	891	598	332	0	0	0	0	0	0	0	0	0
Low_C	1183	891	625	293	0	0	0	0	0	0	0	0
High_D	1556	1263	997	665	372	0	0	0	0	0	0	0
Low_D	1902	1609	1343	1011	718	346	0	0	0	0	0	0
High_E	2324	2031	1765	1433	1140	768	422	0	0	0	0	0
Low_E	2729	2436	2171	1838	1546	1173	827	405	0	0	0	0
High_F	3298	3006	2740	2408	2115	1743	1397	975	569	0	0	0
Low_F	3934	3641	3375	3043	2750	2378	2032	1610	1205	635	0	0
High_G	4825	4532	4266	3934	3642	3269	2923	2501	2096	1527	891	0
Low_G	5844	5552	5286	4953	4661	4289	3943	3521	3115	2546	1911	1019