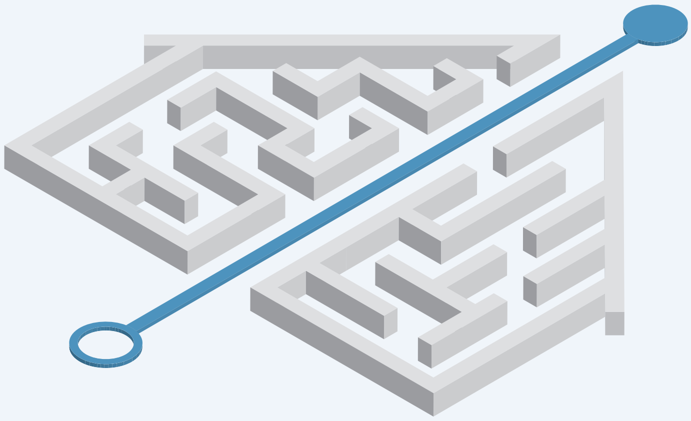

CLOSING THE GAP BETWEEN

DESIGN

&

AS-BUILT PERFORMANCE

END OF TERM REPORT

July 2014

APPENDIX H

ZERO CARBON HUB

The Zero Carbon Hub was established in 2008, as a non-profit organisation, to take day-to-day operational responsibility for achieving the government's target of delivering zero carbon homes in England from 2016. The Hub reports directly to the 2016 Taskforce.

To find out more, or if you would like to contribute to the work of the Zero Carbon Hub, please contact: info@zerocarbonhub.org.

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This document contains Appendix H to the End of Term Report, which is available from www.zerocarbonhub.org

Published July 2014

APPENDIX H: DETAIL OF SAP SENSITIVITY ANALYSIS

This appendix describes the findings of an analysis undertaken by a sub-group within the Tools Work Group to consider the impact on the Dwelling CO_2 Emission Rate (DER) if a SAP input is used which does not match what is built.

It was not possible to look at every possible input discrepancy, so the items chosen were those suggested by members of the Tools Work Group as being potentially significant. A shortcoming of this method is that less easily discoverable items are likely to be under-represented. Furthermore, important items may be unknown to the group and therefore omitted completely. The compiled list of items, based on expert opinion, was in some cases supported by evidence, mostly generated as part of the evidence review for the Performance Gap project (in particular, the SAP audits undertaken as part of the ***House-building Process Review***, summarised in the 'Evidence Update' in Appendix B of the main report[1]). However, the list of issues looked at should not be seen as comprehensive. Over 60 items were suggested, but following initial calculations, the less important ones[2] were removed allowing more time to be spent considering the key items.

1. To download the End of Term Report please visit: www.zerocarbonhub.org/full-lib

2. Items were removed which made little difference to DER, or which were judged by the group to occur rarely in new homes.

Description of Analysis

SAP 2009[3] software was used to calculate the DER[4] ($kgCO_2/m^2$ per year) for a semi-detached archetype dwelling, using specifications chosen to represent a Part L 2013 compliant dwelling. This was used as the starting point for subsequent calculations. For each item on the list of possible discrepancies, a 'with' and 'without' DER result was calculated. The difference between the two results provided a measure of the impact of each item.

The process was repeated using a second archetype dwelling (a mid-floor flat) for a subset of items to check whether the relative significance of input discrepancies changed.

It was recognised that the significance of each discrepancy at the national level depends not only on its impact for an individual home, but also on what proportion of new homes it affects. The latter depends on both the proportion of new homes which have the relevant feature (e.g. a certain type of heating system) and also the probability of a discrepancy occurring in those relevant homes:

Proportion of new homes affected

=

% of new homes with relevant feature
× probability of discrepancy

For example, wind turbines were thought highly likely to be misrepresented where present, but only to be present in a tiny fraction of new homes; so this was judged to have low importance at the national level.[5] An assessment of the probability of misinterpretation was made for each discrepancy based largely on the expert opinion of the group. There was not universal agreement and it was clear that group members felt they had incomplete information on which to judge this. The uncertainty in these estimates is therefore an important limitation of this study.[6] An attempt was made to recognise this by estimating low and high figures as well as a 'best guess' figure, allowing the results to be expressed as a range, rather than just a single number.

An 'Importance Score' was calculated for each item by multiplying the DER impact per home by the estimated proportion of homes affected:

Importance Score

=

DER impact × proportion of new homes affected

---

3. SAP 2012 software was not available in time for use during the study. This is unlikely to make much difference to the results given the fairly minor changes between SAP 2009 and 2012.

4. DFEE (fabric energy efficiency) was also recorded, but this report focuses on DER. DFEE is relevant, but does not change in response to adjustments to heating inputs, so is not as useful as an indicator when comparing a wide range of input sensitivities.

5. This item was therefore removed from the list of items after the first round of calculations.

6. Evidence collected through the Housebuilding Process Review has been used to inform the probabilities of discrepancies occurring.

This was repeated using the low and high estimates of the proportion of homes affected, as well as the best guess figure, to calculate the range.

The unit of measurement of importance has a tangible meaning. It represents the impact of the discrepancy on the average DER of a new home. For example, if the Importance Score is 1, this tells us that the potential saving in correcting this discrepancy would be equivalent to reducing the emissions of every new home by 1 $kgCO_2/m^2$ per year (~5%).

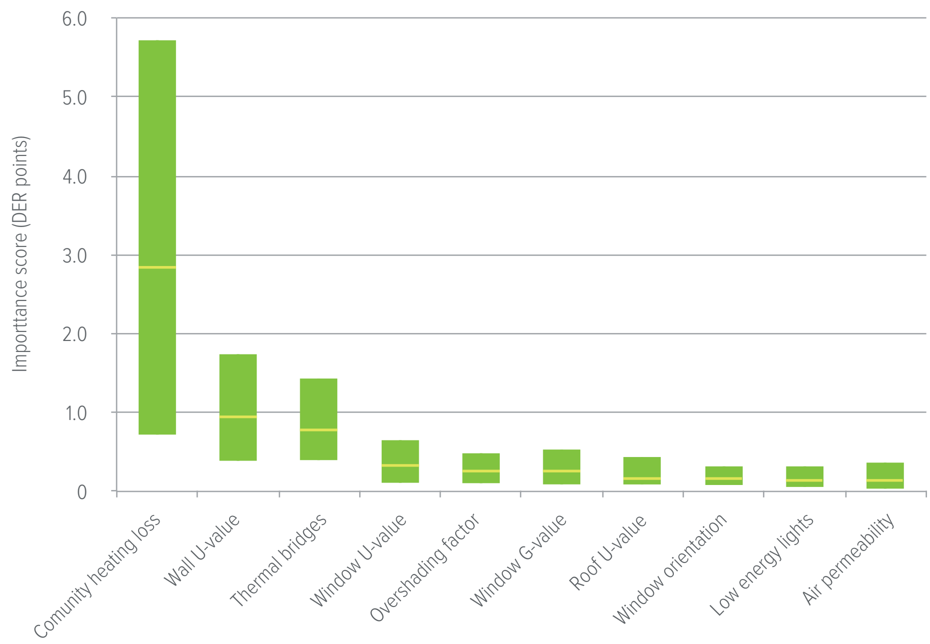
In addition to the above, some inputs were considered in more detail (e.g. a range of discrepancy values) to give a greater understanding of the sensitivity of the output to the input.

Ideally a more statistically robust approach, such as a 'Monte Carlo' approach, would have been used to better understand the uncertainties in the importance scores and to better deal with interactions between different items. However, this would have required a far greater level of understanding of the range and distribution of each potential discrepancy than was available.

Findings

The full results for each discrepancy are tabulated in Reference A. Individual results should be treated with caution because they depend on specific assumptions which in practice may vary greatly from case to case. In other words they are simply a series of examples, rather than necessarily being a representative figure for an issue. However, by looking at the results as a whole, some key themes emerge.

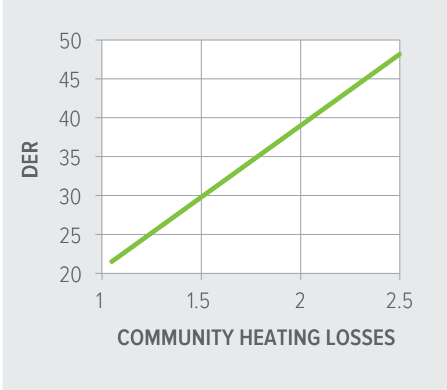
The following graph shows the top ten items, by importance score, which are then discussed in more detail below. The bars on the graph show the range between the importance scores based on the low and high estimates of the proportion of new homes affected; the 'best guess' value is indicated by the marker. For example, the best guess score for the first item is 2.9, but the uncertainty in assumptions means the true value could lie anywhere between 0.7 and 5.7.



1. Community Heating Distribution Losses

The SAP input relating to community heating distribution losses ("distribution loss factor") was identified as a potentially large source of discrepancy. A calculated distribution loss figure can be entered into SAP software, a value from a lookup table used, or a default value assumed. Group opinion was that the tabulated values and the default assumptions are too generous so there is little incentive for a more carefully derived figure to be used. A significant proportion of new homes are built with community systems, especially in London.[7] The impact on DER of a discrepancy can be huge: there are documented cases where well over half of the heat from boilers is lost in transfer to homes,[8] even in fairly new systems, more than doubling fuel consumption. We lack sufficient evidence to know if this is typical or unusual; however, even acknowledging the uncertainty of the assumptions in this study, given the large number of homes potentially affected and the potentially huge impact on DER, this issue is worthy of greater attention.

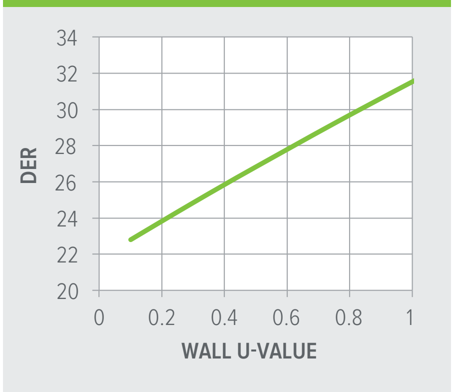
Impact on DER of Change in Community Heating Distribution Losses



2. Wall U-values

Discrepancies relating to wall U-values were also found to be very important. DER is very sensitive to wall U-value and there was judged to be a high chance of a discrepancy between the wall U-value input and the as-built value. If gaps large enough to allow cold air to circulate behind insulation are present, a nominally insulated wall would perform similarly to an uninsulated one, potentially resulting in a rate of heat loss several times worse than calculated[9]. The example modelled 'only' assumed the U-value was doubled from 0.2 to 0.4, so the DER impact would be much greater in the worst cases.

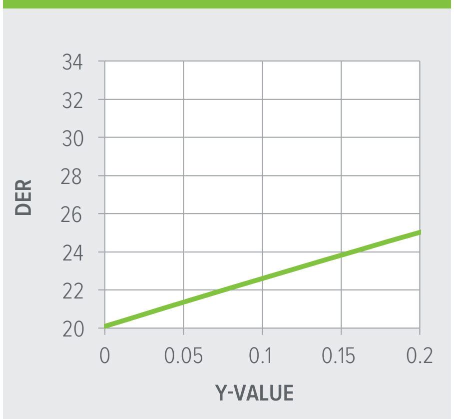
Impact on DER of Change in Wall U-values



3. Thermal Bridges

Numerous issues relating to thermal bridge heat losses were raised by group members. A number of these were looked at with example calculations (see table below). Individually some of these have a significant effect on DER (lintels appear to be the most important), but in the opinion of work group members thermal bridge input discrepancies are likely to be both multiple and very common; for example, accredited values may tend to be used where default values should be[10]. For this reason the importance of this item is best represented for comparison with others as an adjustment to the 'y-value', as a proxy for a range of individual Psi-value and bridge length input discrepancies. In combination these can make a significant difference to the DER and therefore this is seen as another important area of potential discrepancy.

Impact on DER of Change in y-value



7. Planning permission was sought for over 50,000 new homes with community heating systems in London in 2012, according to: http://www.london.gov.uk/sites/default/files/2012%20Monitoring%20Report%203rd%20July%202013.pdf

8. e.g. http://www.pam.ealing.gov.uk/PlanNet/documentstore%5CDC11123716-107-1_AF_A.PDF

9. See pages 42-43 of the Evidence Review Report for examples where this was identified during the evidence collection process. To download the report please visit: www.zerocarbonhub.org/full-lib

10. Extensive evidence was collected for this, as detailed in the Evidence Review Report, for example on pages 23, 25 and 41

TYPE OF THERMAL BRIDGE	PSI-VALUE		DER ($kgCO_2/m^2$)			
	PESSIMISTIC	OPTIMISTIC	PESSIMISTIC	OPTIMISTIC	CHANGE	%
E1 Steel lintels	1	0.5	19.36	18.60	0.76	4.1%
E2 Other lintels	1	0.3	19.36	18.29	1.07	5.9%
E3 Sills	0.08	0.04	18.66	18.60	0.06	0.3%
E4 Jambs	0.1	0.05	18.80	18.60	0.20	1.1%
E5 Ground floor	0.32	0.16	19.00	18.60	0.40	2.2%
E6 Intermediate floor	0.14	0.07	18.77	18.60	0.17	0.9%
E10 Eaves	0.128	0.068	18.69	18.61	0.08	0.4%
E12 Gable	0.48	0.24	18.87	18.60	0.27	1.5%
E16 Corner (normal)	0.18	0.09	18.74	18.60	0.14	0.8%
E18 Party wall	0.12	0.06	18.68	18.60	0.08	0.4%
P1 PW-Ground floor	0.16	0.08	18.67	18.60	0.07	0.4%
P4 PW-Roof	0.24	0.12	18.73	18.60	0.13	0.7%

4. & 6. Window Parameters

There are a number of SAP inputs related to the performance of windows, the most important of which are the U-value and g-value (solar transmittance). Changes in window specification during the build were thought by group members to be common, leading to a high likelihood of discrepancies between the window parameter inputs and the actual build.[11] The DER impact of this is highly variable depending on the change to specification made (it could even improve the DER), but since windows have the highest U-value of any fabric component in modern homes, this item has the potential to have a significant impact. The g-value impact is generally lower, but where standard glazing is replaced with 'solar control' glazing (and not recorded as such in the SAP inputs) there is also the potential for a large DER discrepancy.

5. Overshading Factor

The overshading levels of a new home may not be well known at the initial design stage of a building project, so an assumption of 'average or unknown' is likely to be made, which may not be amended later. Particularly in dense developments, 'above average' may be a more appropriate reflection of what is built in many cases. This input has an important impact on solar gains and therefore on energy consumption and the DER. This was judged by group members to be a common discrepancy.

7. Roof U-value

The U-value assigned to the roof in SAP has a relatively large effect on the DER. This item was rated as having a medium likelihood of being misrepresented in the inputs to a SAP calculation. A common issue raised by members related to the difficulty of insulating the extremities of pitched roofs, due to the narrowing space (i.e. impossible to get 300mm insulation thickness where the space is less than 300mm high).[12]

8. Window Orientation

11. See pages 34-35 of the Evidence Review Report for instances where this was identified during the evidence collection process. To download the report please visit: www.zerocarbonhub.org/full-lib

12. See page 31 of the Evidence Review Report for instances where this was identified during the evidence collection process

Group members thought there was a medium probability of a discrepancy between the SAP input and actual build in relation to window orientation. It is easy to imagine this happening in homes where mirror image layouts (e.g. semi-detached and end-terrace homes) are used. This has a large impact on DER if north-facing glazing is incorrectly recorded as south-facing.

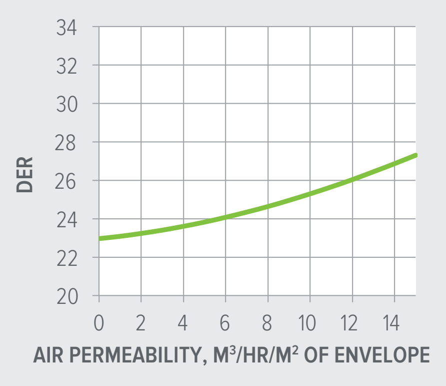
9. Low Energy Lights

The probability of a discrepancy between the proportion of low energy lights assumed in the SAP calculation and the proportion present in the final home was rated as medium by group members. This was thought to be an item where the final design may be likely to vary from the initial assumptions, with the possibility of changes made during the build not being reflected in the final SAP inputs. The DER impact is high if the discrepancy is large (e.g. 50% instead of 100% low energy lights).

10. Air Permeability

Work Group members believed there was a medium likelihood of a discrepancy between the inputted and actual value for air-permeability. This item has a relatively large impact on the DER. In theory this is a well-controlled input since it is one of the few tested features of new dwellings (at least in a sample of cases). However doubts were expressed by some group members as to the consistency of achieved values in non-tested homes. It is worth noting that sensitivity to air permeability is non-linear – at higher levels the result is more sensitive to input changes.

Impact on DER of Change in Air Permeability



Other Items

Several items relating to the use of incorrect dwelling dimensions were mentioned by group members. These are rather difficult to model as individual errors (and would presumably all be fairly unique), but they can have a potentially large impact on the DER. In particular, anything that affects the floor area has a direct impact, since DER is CO_2 emissions per m^2 of floor area. A fairly common example cited by group members was the incorrect recording of the floor area of a 'room-in-the-roof' as the entire floor area, rather than just the heated area. If this were to increase the total floor area by say 10%, the DER would be reduced by around 3 points, which would make this one of the bigger discrepancies. **Therefore discrepancies in dimensions inputs should be treated as potentially important too**.

A number of items relating to heating and hot water systems were mentioned. These also have the potential to have a significant impact on DER. For example, if a secondary heating system is not recorded (particularly electric, where the main heating is gas) this can make a large difference to the DER. A heating efficiency input discrepancy also has the potential to make a big difference (and is probably common due to product switching). Fortunately all new boilers should now be condensing models so the variation in efficiency between different units isn't great, but there is potentially more range in the efficiency of other heating types, especially heat pumps where efficiency is very sensitive to sizing and other design factors. The use of heat pumps in new homes is still fairly unusual, but if their use were to become more common the importance of this item would grow.

Heating controls were mentioned as a building component commonly substituted; however, unreported substitution was not found to have a dramatic effect on the DER unless much worse (and unlikely) substitutions were made.

Thermal mass input discrepancies were thought by group members to be fairly likely, but were found to make a relatively small difference to the DER. Experimenting revealed that in some cases increasing the thermal mass increased the DER and in others it decreased it, but generally it did not make a large difference.

Finally, it is worth keeping in mind that even a very small change in DER can be significant where a home is designed to only just meet the target TER level. Virtually any SAP input can therefore cause a pass to become a fail if its value is changed.

Compound Discrepancies

In practice the gap between as-designed and as-built is likely to be a result of a combination of some or many individual discrepancies. Two examples of this type were considered.

In the first, a 50% increase in the overall 'heat transfer coefficient' was modelled, as a proxy for a group of discrepancies relating to U-values, thermal bridges and air-infiltration inputs. This is probably not an extreme assumption – co-heating tests have been undertaken where much larger discrepancies were observed.

In the second, all the items considered to have high or medium likelihood were compounded into a single example, as far as possible[13]. This calculation was done both with and without the community heating distribution loss discrepancy included, which would not be applicable in homes with individual heating systems. The results are shown in the following table:

COMPOUND DISCREPANCY	MODELLING ASSUMPTIONS		DER ($kgCO_2/m^2$)		
	WITH COMPOUND DISCREPANCY	WITHOUT DISCREPANCY	WITH	WITHOUT	CHANGE
50% increase in heat transfer coefficient	Heat transfer coeff = 148.4	Heat transfer coeff = 98.9	**26.08**	**18.60**	7.48
All likely non-exclusive items (gas boiler)	With all discrepancies	No discrepancies	**33.73**	**17.66**	16.07
All likely non-exclusive items (community heating)	With all discrepancies	No discrepancies	**58.12**	**19.06**	39.06

This shows that, in combination, the input discrepancies identified have the potential to worsen the DER by around 16 points in a home with an individual heating system, or around 39 points where community heating is used. In other words, these discrepancies have the potential to double the CO_2 emissions of a new home. Whilst they are unlikely all to occur at once, this highlights the importance of ensuring that SAP inputs reflect accurately the characteristics of the dwelling that is built. Furthermore, there may be other important discrepancies that have not yet been recognised.

13. The PV discrepancy was also left out because it results in artificially low DERs (e.g. 7) and confuses the comparison. Also, some items are mutually exclusive, such as boiler efficiency and community heating loss factor.

An interesting comparison can be made between the total DER impact calculated by adding up the individual impacts for discrepancy items and the equivalent compound error to give a feel for how strongly interactions between inputs affect the answer. The DER impact of the second composite error in the table was 16.1 points. Adding the individual components gives a slightly lower figure of 15.1. The difference is due to interactions occurring within SAP; for example, if heat losses are higher, more heat is required, so the impact of having lower heating efficiency is increased.

Differences for an alternative dwelling type

The calculations described above were repeated for a mid-floor flat archetype dwelling. In most cases the discrepancies that were most important for the semi-detached dwelling archetype were also the most important for the flat. The following table shows the top 10 ranked issues side-by-side for the two dwelling types looked at:

RANK	SEMI-DETACHED HOUSE	MID-FLOOR FLAT
1	Community heating loss	Community heating loss
2	Wall U-value	Wall U-value
3	Thermal bridges	Thermal bridges
4	Window U-value	Window U-value
5	Overshading factor	Overshading factor
6	Window G-value	Low energy lights
7	Roof U-value	Window G-value
8	Window orientation	Air permeability
9	Low energy lights	Photovoltaic kWp
10	Air permeability	Window orientation

Apart from the non-applicable ‘Roof U-value’ item in the case of a mid-floor flat, the top 10 items are largely the same. Lighting energy makes up a bigger proportion of energy use in flats, so the importance of a lighting input discrepancy is ranked higher. Photovoltaic (PV) is ranked higher, again, because it makes a relatively larger difference to CO_2 emissions, since total emissions are lower.

Summary

- There is a lack of evidence relating to the likelihood of discrepancies existing between SAP inputs and actual build. It was therefore necessary to base this work largely on the combined expert opinion of the Performance Gap project Work Groups.
- The three most important SAP input discrepancies appear to be:
    - Community heating distribution losses;
    - Wall U-values; and
    - Thermal bridges.
- Others found to be important were inputs relating window performance, overshading, roof U-values, proportion of low energy lights, air permeability and PV power rating.
- It is also clear that discrepancies relating to dimensions, especially those which affect floor area, can have a large impact on DER.
- In combination, the input discrepancies identified have the potential to approximately double the DER of a dwelling. In attempting to close the Performance Gap it is therefore critical to ensure these SAP inputs match what is actually built.

Reference A – Full results

Semi-detached house

DISCREPANCY ISSUE	MODELLING ASSUMPTIONS		DER ($kgCO_2/m^2$)			
	WHAT ACTUALLY GOT BUILT	WHAT WAS ASSUMED IN THE SAP CALCULATION	AS BUILT	AS INPUT	CHANGE	%
Air permeability	q50=7	q50=4	18.06	17.35	0.71	4%
Number of fans	4 extract fans	2 extract fans	17.56	17.12	0.44	3%
Sheltered sides	1 sheltered sides	2 sheltered sides	17.76	17.56	0.20	1%
Floor area	Floor area minus $5m^2$	Actual floor area	19.01	17.56	1.45	8%
Room height	Actual room height	Room height less 0.3m	17.56	17.00	0.56	3%
Living area fraction	Living area=50%	Living area=25%	17.93	17.56	0.37	2%
Building perimeter	Actual wall area	Wall area minus 10%	17.56	17.28	0.28	2%
Boiler efficiency	86% efficient cond. boiler	89% efficient cond. boiler	18.14	17.64	0.50	3%
Heating controls	Prog, room stat and TRVs	Full zone control	17.85	17.56	0.29	2%
Secondary heating type	Secondary electric fire	Secondary gas fire	18.66	18.03	0.63	3%
Cylinder heat loss	Cylinder loss=2.25kWh/day	Cylinder loss=1.8kWh/day	17.75	17.56	0.19	1%
Low water consumption	125l/p/d option not selected	125l/p/d option selected	17.76	17.56	0.20	1%
Community heating loss	Dist. loss factor=2	Dist. loss factor=1.1	34.13	19.81	14.32	72%
Low energy lights	50% LELs	100% LELs	18.63	17.56	1.07	6%
Thermal mass	150 kJ/m^2K	250 kJ/m^2K	18.69	18.60	0.09	0%
PV kWp	1.5kWp	2kWp	9.36	6.63	2.73	41%
Thermal bridges	y=0.15	y=0.08	19.85	18.26	1.59	9%
Floor U-value	U=0.4	U=0.25	19.06	18.23	0.83	5%
Wall U-value	U=0.4	U=0.2	19.69	17.76	1.93	11%
Roof U-value	U=0.3	U=0.14	18.51	17.62	0.89	5%
Window orientation	½ faces north, ½ east	½ faces south, ½ east	19.33	18.51	0.82	4%
Window U-value	U=1.8	U=1.2	18.29	17.19	1.10	6%
Window g-value	G=0.4	G=0.7	18.18	17.28	0.90	5%
Overshading factor	Above average shading	Average shading	18.26	17.56	0.70	4%

Semi-detached house

RANK	ITEM	DER IMPACT	% OF HOMES AFFECTED			SIGNIFICANCE SCORE		
			LOW ESTIMATE	BEST ESTIMATE	HIGH ESTIMATE	LOW ESTIMATE	BEST ESTIMATE	HIGH ESTIMATE
1	Community heating loss	14.32	5%	**20%**	40%	0.72	**2.86**	5.73
2	Wall U-value	1.93	20%	**50%**	90%	0.39	**0.97**	1.74
3	Thermal bridges	1.59	25%	**50%**	90%	0.40	**0.80**	1.43
4	Window U-value	1.1	10%	**30%**	60%	0.11	**0.33**	0.66
5	Overshading factor	0.7	15%	**40%**	70%	0.11	**0.28**	0.49
6	Window g-value	0.9	10%	**30%**	60%	0.09	**0.27**	0.54
7	Roof U-value	0.89	10%	**20%**	50%	0.09	**0.18**	0.45
8	Window orientation	0.82	10%	**20%**	40%	0.08	**0.16**	0.33
9	Low energy lights	1.07	5%	**15%**	30%	0.05	**0.16**	0.32
10	Air permeability	0.71	5%	**20%**	50%	0.04	**0.14**	0.35
11	PV kWp	2.73	2%	**5%**	15%	0.05	**0.14**	0.41
12	Floor U-value	0.83	5%	**15%**	25%	0.04	**0.12**	0.21
13	Floor area	1.45	1%	**5%**	10%	0.01	**0.07**	0.15
14	Sheltered sides	0.2	10%	**30%**	50%	0.02	**0.06**	0.10
15	Low water consumption	0.2	10%	**25%**	50%	0.02	**0.05**	0.10
16	Boiler efficiency	0.5	5%	**10%**	25%	0.03	**0.05**	0.13
17	Number of fans	0.44	2%	**10%**	20%	0.01	**0.04**	0.09
18	Secondary heating type	0.63	1%	**5%**	20%	0.01	**0.03**	0.13
19	Heating controls	0.29	2%	**10%**	25%	0.01	**0.03**	0.07
20	Room height	0.56	1%	**5%**	10%	0.01	**0.03**	0.06
21	Thermal mass	0.09	10%	**30%**	60%	0.01	**0.03**	0.05
22	Cylinder heat loss	0.19	2%	**10%**	25%	0.00	**0.02**	0.05
23	Living area fraction	0.37	1%	**5%**	10%	0.00	**0.02**	0.04
24	Building perimeter	0.28	1%	**5%**	10%	0.00	**0.01**	0.03

Mid-floor flat

DISCREPANCY ISSUE	MODELLING ASSUMPTIONS		DER ($kgCO_2/m^2$)			
	WHAT ACTUALLY GOT BUILT	WHAT WAS ASSUMED IN THE SAP CALCULATION	AS BUILT	AS INPUT	CHANGE	%
Air permeability	q50=7	q50=4	16.41	15.72	0.69	4%
Number of fans	4 extract fans	2 extract fans	16.22	15.68	0.54	3%
Sheltered sides	1 sheltered sides	2 sheltered sides	16.10	15.93	0.17	1%
Floor area	Floor area minus 5m^2	Actual floor area	16.67	15.93	0.74	5%
Room height	Actual room height	Room height less 0.3m	15.93	15.36	0.57	4%
Living area fraction	Living area=50%	Living area=25%	16.06	15.85	0.21	1%
Building perimeter	Actual wall area	Wall area minus 10%	15.93	15.70	0.23	1%
Boiler efficiency	86% efficient cond. boiler	89% efficient cond. boiler	16.44	16.00	0.44	3%
Heating controls	Prog, room stat and TRVs	Full zone control	16.05	15.93	0.12	1%
Secondary heating type	Secondary electric fire	Secondary gas fire	16.50	16.27	0.23	1%
Cylinder heat loss	Cylinder loss=2.25kWh/day	Cylinder loss=1.8kWh/day	16.16	15.93	0.23	1%
Low water consumption	125l/p/d option not selected	125l/p/d option selected	16.15	15.93	0.22	1%
Community heating loss	Dist. loss factor=2	Dist. loss factor=1.1	35.21	20.55	14.66	71%
Low energy lights	50% LELs	100% LELs	17.04	15.93	1.11	7%
Thermal mass	150 kJ/m^{2}K	250 kJ/m^{2}K	16.31	15.93	0.38	2%
PV kWp	1.0kWp	1.4kWp	9.25	6.58	2.67	41%
Thermal bridges	y=0.15	y=0.08	16.81	16.19	0.62	4%
Wall U-value	U=0.4	U=0.2	17.70	15.85	1.85	12%
Window orientation	½ faces north, ½ east	½ faces south, ½ east	16.16	15.57	0.59	4%
Window U-value	U=1.8	U=1.2	16.39	15.70	0.69	4%
Window G-value	G=0.4	G=0.7	16.41	15.93	0.48	3%
Overshading factor	Above average shading	Average shading	16.35	15.93	0.42	3%

Mid-floor flat

RANK	ITEM	DER IMPACT	% OF HOMES AFFECTED			SIGNIFICANCE SCORE		
			LOW ESTIMATE	BEST ESTIMATE	HIGH ESTIMATE	LOW ESTIMATE	BEST ESTIMATE	HIGH ESTIMATE
1	Community heating loss	14.66	5%	**20%**	40%	0.73	**2.93**	5.86
2	Wall U-value	1.85	20%	**50%**	90%	0.37	**0.93**	1.67
3	Thermal bridges	0.62	25%	**50%**	90%	0.15	**0.31**	0.56
4	Window U-value	0.69	10%	**30%**	60%	0.07	**0.21**	0.41
5	Overshading factor	0.42	15%	**40%**	70%	0.06	**0.17**	0.29
6	Low energy lights	1.11	5%	**15%**	30%	0.06	**0.17**	0.33
7	Window G-value	0.48	10%	**30%**	60%	0.05	**0.14**	0.29
8	Air permeability	0.69	5%	**20%**	50%	0.03	**0.14**	0.35
9	PV kWp	2.67	2%	**5%**	15%	0.05	**0.13**	0.40
10	Window orientation	0.59	10%	**20%**	40%	0.06	**0.12**	0.24
11	Thermal mass	0.38	10%	**30%**	60%	0.04	**0.11**	0.23
12	Low water consumption	0.22	10%	**25%**	50%	0.02	**0.06**	0.11
13	Number of fans	0.54	2%	**10%**	20%	0.01	**0.05**	0.11
14	Sheltered sides	0.17	10%	**30%**	50%	0.02	**0.05**	0.09
15	Boiler efficiency	0.44	5%	**10%**	25%	0.02	**0.04**	0.11
16	Floor area	0.74	1%	**5%**	10%	0.01	**0.04**	0.07
17	Room height	0.57	1%	**5%**	10%	0.01	**0.03**	0.06
18	Cylinder heat loss	0.23	2%	**10%**	25%	0.00	**0.02**	0.06
19	Heating controls	0.12	2%	**10%**	25%	0.00	**0.01**	0.03
20	Building perimeter	0.23	1%	**5%**	10%	0.00	**0.01**	0.02
21	Secondary heating type	0.23	1%	**5%**	20%	0.00	**0.01**	0.05
22	Living area fraction	0.21	1%	**5%**	10%	0.00	**0.01**	0.02

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