

PROVISIONAL

Methodology used for the SAP assessment of typical property types for retrofit

The AECB's 'CarbonLite Retrofit' (CLR) project has modelled the energy savings from three typical house types using PHPP in order to carry out a cost-benefit analysis of a range of retrofit packages.

Since it is recognised that few retrofit projects will be able to afford comprehensive use of PHPP, modelling of the same packages was carried out using SAP to see if the results are comparable enough (a) to provide further reassurance regarding the results of the PHPP analysis and (b) to indicate the extent to which SAP analysis could be used as a cheaper alternative.

This report describes how the SAP modelling was carried out to provide a record of this part of the CLR project and also aims to help SAP assessors to make sense of a project that primarily talks in terms of the PHPP approach. It should be noted that the results are provisional and further work will be needed to develop a robust procedure and agree conventions, especially in relation to the way that thermal bridging losses are treated.

The assessments were carried out using "full SAP" software (SAP 2012 v9.92, specifically NHER Plan Assessor v6.1) rather than Reduced Data SAP (RDSAP) so that the effect of different air permeability rates and assumptions regarding thermal bridging losses could be included.

Differences between SAP and PHPP

Many proponents of PHPP do not currently consider SAP (or RDSAP) to provide an adequately accurate indicator of thermal post retrofit performance, and it is certainly true that PHPP takes more details into account (e.g. areas of window frames, length of ducting for MVHR systems) that are potentially significant for homes designed to the Passive House standard. However, it is less clear that this additional detail provides more accuracy for the baseline (pre-retrofit) assessment which is just as important for the estimation of energy savings from an improvement package.

SAP and PHPP are both static mathematical models that predict energy consumption in dwellings based on the property dimensions, the assumed thermal performance of the fabric and systems, plus assumptions regarding the effect of occupants and future weather conditions. Therefore any claims of "accuracy" need to be treated with some caution. However, that does not mean that they are not useful as an aid to design and decision making.

A comparison of the SAP and PHPP methodologies is complicated by the fact that different conventions are used regarding measurements and the way air permeabilities (air pressure test results) are incorporated. SAP uses internal measurements and PHPP uses external measurements, which has a big impact on the way that thermal bridging is dealt with, especially at corners. With respect to air permeability, SAP uses $\text{m}^3/\text{m}^2 \cdot \text{h}$ @ 50Pa whereas PHPP uses air changes per hour @ 50Pa.

However, the most significant difference between the two methodologies is the assumptions regarding internal heat gains. SAP assumes much higher heat gains than are assumed by PHPP, due to PHPP seeking to minimise risk of underestimating the space heating requirement and SAP assuming typical characteristics of existing dwellings. This reflects the different backgrounds to the

methodologies. PHPP is designed to show that the building fabric is good enough to meet the Passivhaus standard and it therefore makes sense that it shouldn't be possible to make up for a poor building fabric by using poor appliances, or to have a Passivhaus which meets the standard using bad appliances but fails when they are updated. On the other hand, SAP was developed to compare the energy performance of dwellings and encourage the uptake of improvements, so typical values reflect reality better and provide the opportunity to show the benefits of improvements such as hot water cylinder insulation and low energy lights.

This difference the assumptions regarding internal heat gains becomes more significant as heat losses decrease but even for a typical existing dwelling, it means that the outputs produced by SAP and PHPP are not directly comparable. The latest versions of SAP do allow for lower gains in the DER calculation for new homes but these are not applied to the SAP calculation for existing homes.

Dwelling types modelled

The project was based on the modelling of three house types:

- A two-bedroom detached bungalow
- A two-storey semi-detached house
- A three storey mid terrace town house

The bungalow and semi-detached house were simple rectangular shapes but the town house had a two storey rear extension, resulting in L-shaped plans for the ground and first floors. There were no 'rooms in the roof'.

Scale drawings were provided from which the dimensions of the external elements were extracted based on the SAP conventions. Baseline SAP assessments were then carried out based on the following assumptions:

- Thermal mass parameter - Medium i.e. $250 \text{ kJ/m}^2\text{K}$ (This is the default used by RDSAP in all cases, although it might be argued that a higher figure would be more appropriate for these scenarios assuming solid ground floors and dense blockwork or brick walls. SAP defines an indicative value of $450 \text{ kJ/m}^2\text{K}$ to represent 'High' thermal mass although a calculated value can be entered. The PHPP modelling assumed $156 \text{ Wh/m}^2\text{K}$, which equates to $561.6 \text{ kJ/m}^2\text{K}$).
- Two sides sheltered (This is the default used by RDSAP in all cases, although the semi-detached house might only have one side sheltered and the detached bungalow might have none. Each sheltered side is assumed by SAP to reduce the infiltration rate by 7.5%. The PHPP modelling assumed several sides exposed with moderate screening.
- U-values as used in PHPP: walls $1.35 \text{ W/m}^2\text{K}$, roofs $0.21 \text{ W/m}^2\text{K}$, suspended floors $1.62 \text{ W/m}^2\text{K}$, solid floors $2.14 \text{ W/m}^2\text{K}$, party walls $1.20 \text{ W/m}^2\text{K}$, windows $2.62 \text{ W/m}^2\text{K}$, doors $3.00 \text{ W/m}^2\text{K}$. (Note that in PHPP, U-values are calculated for each window but SAP uses an average.)
- γ -value 0.15 (This is the default used by RDSAP in all cases, although full SAP does allow the calculation of the γ -value from individual ψ -values and lengths if ψ -values are available. For PHPP, the thermal bridges were modelled in THERM and added individually.)
- Natural ventilation - 8 air changes per hour (or 10 for the town house)

- No open fireplaces, open flues or flue-less gas fires
- Heating by mains gas, condensing instantaneous combination boiler and radiators, efficiency 83%, high temperature design flow temperature (>45°C), pump in heated space and installed pre 2013 (no secondary heating)
- Heating controls: programmer, room stat and TRVs,
- Hot water from boiler, water use > 125 litres/person/day (In SAP, this affects the heat gains from the hot water system and therefore the estimated space heating requirement. In PHPP, heat gains from the hot water system are not part of the heat demand calculation.)
- 100% low energy lights (In SAP, this affects the heat gains from lighting and therefore the estimated space heating requirement. In PHPP, heat gains from lighting are not part of the heat demand calculation.)

Improvement packages modelled

The effects of four different improvement packages were modelled with each house type as follows:

- Cost prioritised with internal wall insulation and centralised MEV
- Cost prioritised with external wall insulation and centralised MEV
- CO₂ prioritised with internal wall insulation and MVHR
- CO₂ prioritised with external wall insulation and MVHR

The ‘cost prioritised’ packages were designed to achieve a minimum of a 50% reduction in CO₂ emissions from space heating and the ‘CO₂ prioritised’ packages were designed to achieve a minimum of a 70% reduction in CO₂ emissions from space heating.

The following table summarises the U-values and air change rates defined for each of these packages:

	Cost prioritised		CO ₂ prioritised	
	IWI and MEV	EWI and MEV	IWI and MVHR	EWI and MVHR
Wall U-value	0.32	0.12	0.32	0.09
Solid floor U-value	0.10	0.10	0.10	0.10
Suspended floor U-value	0.18	0.18	0.15	0.12
Roof U-value	0.17	0.17	0.12	0.12
Window U-value	2.5	2.5	1.47	1.01
Door U-value	0.8	0.8	0.8	0.8
ACH @ 50Pa	3.0	3.0	1.5	1.5

Note that for the ‘cost prioritised’ packages, the average window U-value is only reduced from 2.6 W/m²K to 2.5 W/m²K, based on the assumption that just the glazing is being replaced with similar when the seals go, so the frame remains the same. This is a very conservative assumption. If the whole window was replaced then the U-value would be expected to be reduced to 1.6 W/m²K or better to meet the requirements of Part L2A. Also, RDSAP assumes a U-value of 1.6 W/m²K for glazing replacement where existing upvc frames are retained.

In all cases, the heating system was assumed to be improved to efficiency 90%, with low temperature design flow temperature (<35°C), weather compensation and pump in heated space installed 2013 or later.

Dealing with air permeability

The air permeability for the packages was defined in terms of air changes per hour @ 50 Pa as used in PHPP, so consideration was given to converting these values to m³/m².h @ 50 Pa for entry into the SAP software. However, the SAP calculation estimates the air change rate at normal pressure by simply dividing the m³/m².h @ 50 Pa figure by 20 without taking account of the actual envelope area. Therefore it was decided to use the air changes per hour figures in the SAP assessments to avoid introducing an additional variable factor that would make the results less comparable. (Also, it was felt that most SAP assessors would be happy to use these air permeability values where MEV and MVHR were specified).

Modelling thermal bridges

The SAP calculation procedure for existing homes bases the additional heat losses from non-repeating thermal bridges on a default ψ -value of 0.15 W/m²K. There are currently no conventions regarding how this might be revised for assessments of deep retrofits. However, the 'full SAP' software does allow the entry of user-defined ψ -values to enable a ψ -value to be calculated since this is an option for the assessment of new build homes. Therefore it is possible to model this using SAP software provided that appropriate ψ -values are available.

However, the ψ -values that were calculated for the PHPP modelling could not be used due to the different measurement conventions used for PHPP (external measurements instead of internal). Therefore revised ψ -values based on internal measurements had to be estimated and figures for this purpose were provided by Tim Martel, who was carrying out the PHPP modelling. These figures included ψ -values for junctions between internal walls and external walls, ground floors and lofts that are not normally considered in new build SAP assessments. The resultant calculated ψ -values that were used are summarised in the following table:

y-values (W/m²K)	Cost prioritised		CO₂ prioritised	
	IWI and MEV	EWI and MEV	IWI and MVHR	EWI and MVHR
Bungalow	0.136	0.185	0.118	0.12
Semi-detached house	0.179	0.194	0.153	0.102
Three storey town house	0.255	0.251	0.216	0.123

Note that in most cases the calculated values are higher than the SAP default of 0.15 W/m²K, which is surprising and therefore, further work is needed to confirm that appropriate internal ψ -values have been used. It would also be useful to compare the heat loss coefficients (W/K) produced by PHPP and SAP as these should be the same irrespective of measurement conventions (although the different ways that air permeability is treated to calculate ventilation loss will also affect this).

Outputs compared

The outputs compared were:

- Average whole house temperature during the heating season
- Specific Space Heat Demand (SHD) – kWh/m² per year
- Gas used for space heating – kWh per year
- Reduction in space heating energy - %
- CO₂ emitted from space heating (based on using natural gas) – tonnes per year
- Reduction in space heating related CO₂ emissions - %

One feature of the PHPP analysis for this project is that the average whole house temperature during the heating season has been assumed (and directly modelled) to increase from 17°C before retrofit to 20°C after the retrofit to reflect the fact that occupiers will tend to choose greater comfort levels after retrofit. The current version of SAP is not able to replicate this as a design value but the average whole house temperature during the heating season is estimated by SAP as part of the calculation procedure and this does typically increase from about 17°C to 18.5-19.5°C depending on the extent of insulation. Therefore SAP does effectively account for some ‘comfort taking’. The average whole house temperature is reported in SAP as ‘mean internal temperature (for the whole dwelling)’ and can be obtained from row 93 of the SAP worksheet (although the average annual value needs to be calculated manually from the 12 monthly figures provided).

Specific Space Heat Demand (SSHD) is reported as space heating requirement (kWh/m²/year) in box 99 of the SAP worksheet and this is generally lower than the SHD figures estimated by PHPP. This is expected as SAP estimates the space heating requirement net of the useful gains whereas PHPP reports the total heat demand regardless of how this is met (i.e. before any allowance for gains other than solar gains). Therefore these values are not directly comparable. (The Fabric Energy Efficiency from SAP might be a better comparator as this excludes the gains from the heating and hot water system and assumes other internal gains are lower, although it also doesn’t allow for any heat recovery from MVHR).

The gas used for space heating (kWh per year) is reported in row 211 of the SAP worksheet (assuming there is one heating system). While we might hope that the results for this would be comparable between SAP and PHPP, we know this is unlikely from the differences in the methodologies. (Interestingly, the SAP result is not always lower – for the town house SAP estimates higher space heating consumption than PHPP does.) However, what we have found is that the percentage reductions in space heating energy do correlate quite well, especially those for the semi-detached house type.

With regard to CO₂ emissions from space heating, there are different conversion factors used by PHPP (about 0.25 kgCO₂/kWh) and SAP (0.216 kgCO₂/kWh). In the case of SAP, we have recorded the emissions for use of gas only (row 261 of the SAP worksheet), i.e. we have not added in the emissions due to electricity for pumps and fans that SAP also estimates. Again the percentage reduction figures correlate much better between the two methodologies than the actual estimated values.