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Contents

1. Introduction

This report outlines a detailed analysis on the gap between PHPP version 7.2 and an adjusted SAP 2009 version 9.90 calculation model which has been amended and comprises the major changes introduced in SAP 2012. Apart from this, the general transferability of input data and modelling output parameter from PHPP to SAP is examined for several reasons as follows.

a) As the PHPP spreadsheet is the standard design and verification tool for certifying that a dwelling achieves the Passivhaus standard, it is assumed that it will always be first part in the planning process and thus already available before compliance check through SAP is carried out.

b) The amount of input data in PHPP compared to SAP is more detailed; making data export easier and less additional manual input should be required. The final aim of the analysis is to provide a reliable SAP model that would be the basis for compliance check.

The report divides into three main sections. The first part describes the methodology, followed by a section on the microscopic gap analysis applied and another section on the macroscopic gap analysis. Afterwards, the report draws to a conclusion with a summary and an outlook for further investigation.

2. Methodology

Although both models apply basic steady state equations for estimating heat loss or calculations incorporating empirical values, fundamental implementation discrepancies exist. In order to determine the gap between both models, two different approaches have been used as outlined in the following:

Microscopic gap analysis

The microscopic gap analysis (MIA) examines model discrepancies from a low level and compares necessary modelling input parameters for both models with each other. The following steps have been undertaken:

1. Listing and comparing all input parameters that are necessary to produce a SAP rating of a dwelling previously assessed in PHPP (Appendix A)
2. Classifying occurring discrepancies and outline how they could be overcome
3. Porting PHPP model input parameters to SAP spreadsheet
4. Analyse SAP rating results

Macroscopic gap analysis

In the macroscopic gap analysis (MAA), PHPP model outputs have been extracted to reduce the need for fundamental user input when producing SAP ratings based on a PHPP model. The following steps have been undertaken:

1. Extract PHPP model output parameters that are equivalent to the SAP energy requirements fuel for space heating, hot water as well as electricity for lighting and auxiliary
2. Generate SAP ratings
3. Compare SAP ratings with results from microscopic gap analysis

The analysis was supported by the examination of PHPP spreadsheets of five different Passive Houses listed in Table 1. For the houses technical documentation was available as well as assessments using BRE'sown SAP software bsap.

Table 1: Examined Passive House dwellings

ID	Address	House type
Stories Mews	Camberwell Passive House, 5 Stories Mews, London	Mid-terraced
Kennett Road	Kennett Road, Oxford	Detached
Larch House	Hwylus Haus, Ebbw Vale	Detached
John Rous	John Rous Avenue, Coventry	Detached
Bridgend	1 Cae Gleision, Bridgend	Semi-detached

3. Microscopic gap analysis

A list was generated that compares all input and modelling parameters that are needed to produce a SAP rating. The list has been grouped according to main modelling steps and can be found in Appendix A. From the list, major and minor modelling discrepancies were deduced and are outlined in the following sub-sections.

Afterwards, a SAP calculation model in a spreadsheet was populated primarily with equivalent input parameters from the PHPP spreadsheet. If parameters could not be made available this way, the necessary data was inputted manually. In order to reduce the amount of manual input needed, assumptions and standards that could generally be deduced from a newly built Passivhaus dwelling were taken into account. Throughout the calculation steps, the origin of data and modelling parameters has been highlighted in the spreadsheet with a respective colour as depicted in Figure 1. Additionally, comments were made to the spreadsheet cells.

SAP2009 V9.90, adjusted to match major changes from SAP 2012						
1. Overall dwelling dimensions					Description of current model:	
	Area (m^2)	Average storey height (m)	Volume (m^3)		Stories Mews	
Basement			0.00			
Ground floor	74.48	2.28	169.81			Manual input necessary!!!
First floor	57.14	2.55	145.71			
Second floor			0.00			Direct PHPP import possible
Third floor			0.00			
Fourth floor			0.00			Values can be locked for a Passive house
Living area fraction	0.163					
Total floor area TFA (m^2)	131.62					Should be verified through further calculations
Dwelling volume (m^3)	315.52					
						Not necessary as pressurisation test has been carried c
2. Ventilation rate						
	Main heating	Secondary heating	Other	Total	m^3/hr	
Number of chimneys	0	0	0	0	0	
Number of open flues	0	0	0	0	0	
Number of intermittent fans				4	40	
Number of passive vents				0	0	
Number of flueless gas fires				0	0	

Figure 1: Screen grab from a part of the populated SAP spreadsheet. Cells are highlighted with colours denoting the origin of each input or modelling parameter.

3.1. Methodological discrepancies

1. Dimensions

   Whereas PHPP measures all dimensions externally, SAP uses internal dimensions as reference. This leads to a fundamental difference in the determination of thermal bridge heat loss as well as general heat transmission loss through external building elements.

   → As geometry and architecture can vary significantly between dwellings, it seems difficult to determine a relation between internal and external dimensions. For this reason, it is currently necessary to manually input SAP dimensions.

2. Floor area

   PHPP uses “Treated Floor Area” as reference which basically comprises of heated floor area plus further additions for rooms with specific purpose or with reduced room height, but excludes walls and stairs. SAP uses the whole internal floor surface area, i.e. internal walls and stairs are ignored, and is called “Total Floor Area” as reference. This area is then divided into living room area and rest of the dwelling.

   → Living room fraction should be manually entered by user.

   → Examination of PHPP Treated Floor Area and SAP Total Floor Area have shown a nearly linear relation for the five dwellings analysed as shown in Figure 2.

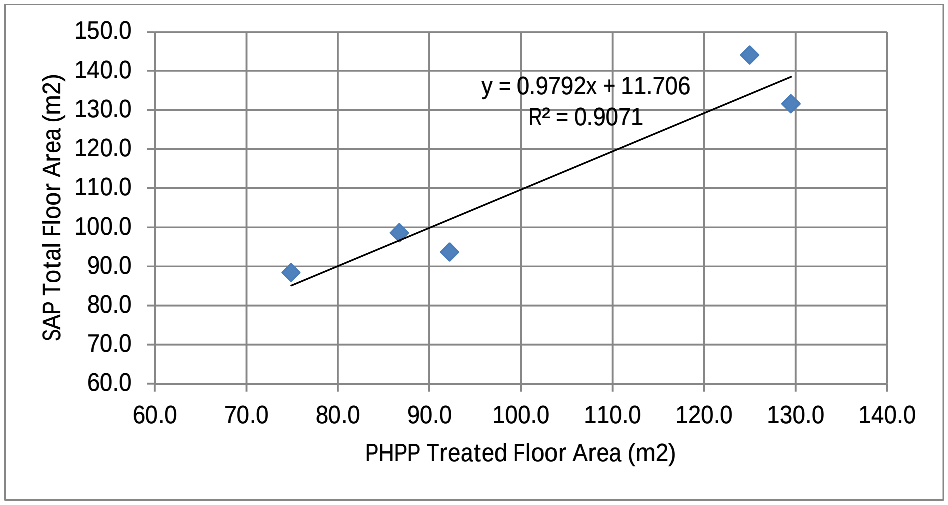

Figure 2: Relation between PHPP Treated Floor Area and SAP Total Floor Area for the examined buildings

Although, PHPP Treated Floor Area could be calibrated to retrieve SAP Total Floor through the linear regression equation as shown in Figure 2, it would not be statistically rigour based on the sample size. Floor area has a high impact on the final SAP rating and should therefore be determined as precise as possible. In general, the smaller the floor area the lower the SAP rating for a specific dwelling although the magnitude can vary from building to building as shown in Figure 3. The figure shows the absolute decrease in SAP rating points when reducing the SAP total floor area by percentage. Note that values from Figure 3 only apply for a range between 85% and 100% of the respective SAP floor area of each dwelling. In this range the relation between SAP rating and floor area is nearly linear. 85 % or 15% reduction represents the maximum relative difference between PHPP Treated Floor Area and SAP Total Floor area for the analysed buildings.

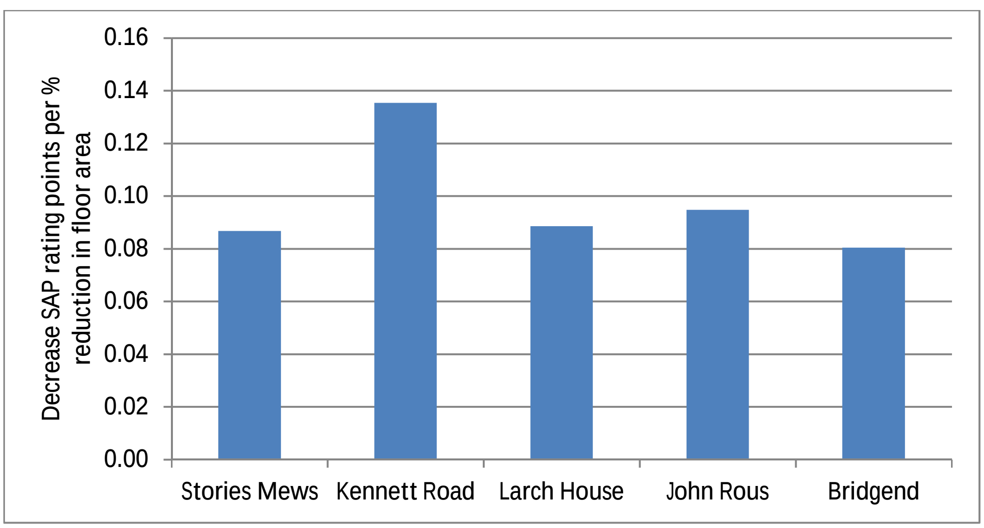

Figure 3: Absolute decrease in SAP rating points per percentage reduction in floor area for a range of up to 85 % of the actual total SAP floor area.

3. Effective air change rate

The effective air change rate determined for a dwelling through PHPP is in general lower than in SAP leading to reduced estimates for ventilation and infiltration heat losses within PHPP. In order to examine the difference in effective air change rate, as many modelling input parameters as possible have been transferred from PHPP directly or through calculation to SAP. The transferred parameters are the following:

- Number of intermittent fans
- Air permeability rate (q_{50})
- Effective air change rate for mechanical ventilation
- Heat recovery efficiency

Although the same input parameters have been used in both energy models, the examined dwellings still show that PHPP effective air change rates are in average about 61 % lower than in SAP. This is due to different basic assumptions with regards to air flow through openings, shelter factors as well as SAP in-use factors that lower the efficiency of mechanical ventilations systems. The difference between both model's effective air change rates per dwelling is shown in Figure 44.

→ No apparent relation between both modelling parameters has been determined.

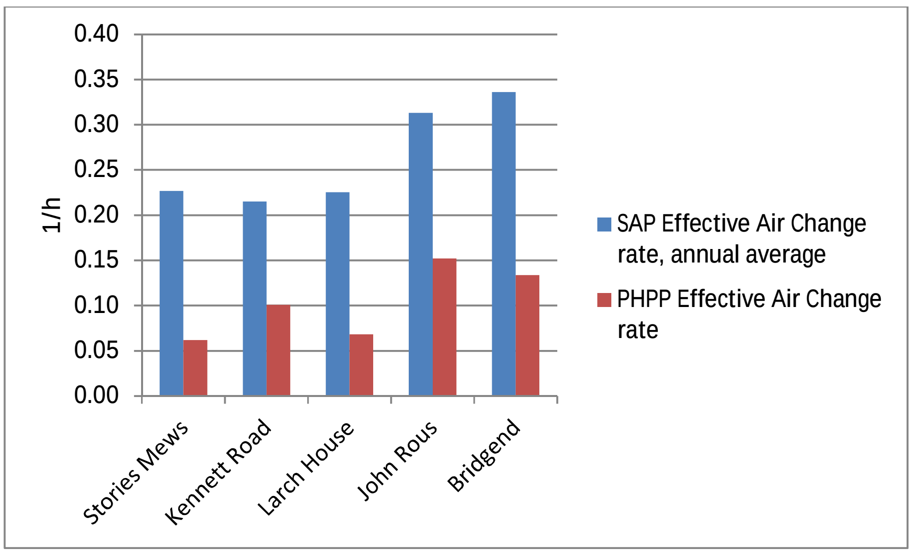

Figure 4: Comparison of effective air change rate

4. Thermal bridges

Due to fundamental differences in the use of dimensions neither PSI-values nor building element lengths can be extracted from PHPP. Thus, the comparison of thermal bridge heat losses is not reasonable. Where possible the necessary thermal bridge factor for the SAP assessments were determined from the original documentation submitted as part of the Passivhaus certification process and manually adjusted from external to internal dimensions.

→ Manual user input of PSI-values and internal lengths is required either in SAP, or by making use of the existing conversion tool in PHPP, but could also need additional thermal modelling in order to provide SAP values that resemble the low PSI-values achieved in a Passivhaus.

5. Internal heat gains
   Whereas PHPP allows detailed specification of gains through electric appliances and household activities, SAP assumes gains are mainly indirectly related to floor surface area through the number of occupation and hot water consumption. SAP internal heat gains per SAP Total Floor Area are in general about 100% higher than gains in PHPP per Treated Floor Area for the dwellings examined. Figure 5 compares the internal gains in each dwelling.
   → No simple correlation between both models was detected. Further analysis would be required to examine and overcome the modelling gap.

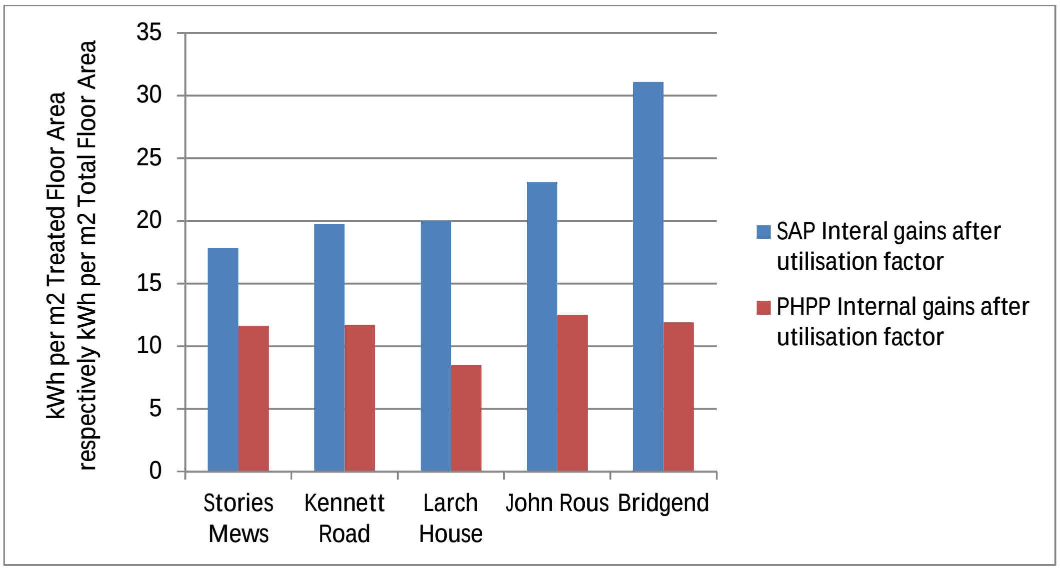

Figure 5: Comparison of internal gains per respective reference floor area in both models

6. Determination of heating duration per year
   In order to calculate the annual heat demand, both models follow the basic approach of applying heating degree days to a heat loss rate. PHPP determines the actual number of heating degree days for 20°C inside temperature. SAP, however, uses a methodology where the mean internal temperature is determined from two zones, the living room heated to a temperature of 21°C while the remainder of the dwelling is heated to 18°C. Also, in SAP the heating duration is adjusted to reflect type of heating emitter and temperature control installed.
   → It would be possible to extract the equivalent of heating degree days for each building from SAP and compare them with PHPP results. This would need further analysis.

3.2. Minor discrepancies

7. Effective U-values for windows

   SAP uses effective U-values through reduction of window U-values by about 4% in order to take account for internal curtains. However, it seems unreasonable to assume the usage of internal curtains in a Passivhaus. For this reason, the reduction factor was ignored for the analysis.

8. Thermal mass

   Although thermal mass is used for a different purpose in both energy models, this input parameter can be transferred from PHPP to SAP after adjustment. In PHPP, thermal mass is related to treated floor area and in SAP to total floor area. As both parameters are known at this step in the modelling procedure, the extraction and calculation could be carried out automatically.

9. Water heating consumption

   Both models assume generic hot water consumption based on the number of occupants. However, SAP adds an extra amount of hot water per day. Thus, a comparison of absolute annual fuel demand for water heating (solar hot water provision deducted) does not reveal a strong correlation (R^2=0.38) based on a linear regression model. However, when comparing demand figures per respective reference floor area and number of occupants, the correlation between PHPP and SAP outputs increases significantly. A linear regression model with a coefficient of determination R^2 of 0.83 as shown in Figure 6 can be achieved this way.

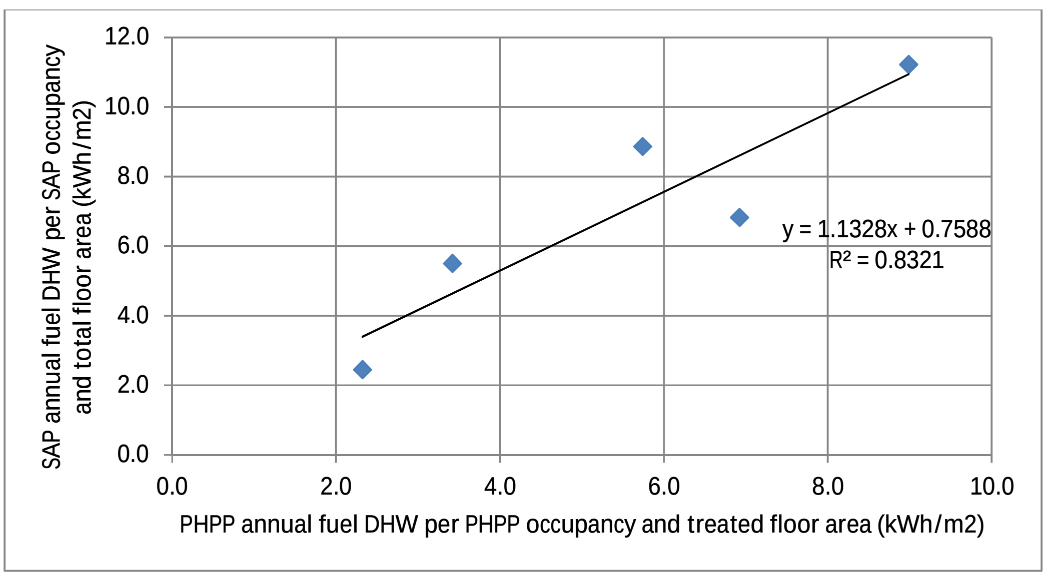

Figure 6: Annual fuel demand for water heating per respective reference floor area and occupancy as determined through PHPP and SAP

10. Solar gains

    Solar gains in both models are calculated through the same type of equation as listed below. Although each separate factor of the equation can be specified in PHPP in more detail, the majority of them can be manipulated in SAP as well.

$$G_{solar} = A_w * g * FF * x * S$$

Here A_w is the window area, g is the g-value of the glazing, FF is the frame factor, x is a reduction factor representing orientation and physical condition of a windows and S is the solar flux. The only factors that cannot be influenced within SAP are the reduction factor which is based on broad estimates as well as solar flux that is fixed through climate data. The reduction factor within PHPP is generally lower than in SAP. This leads to a difference in solar gains in both models.

11. Efficiency

    Efficiencies of building services technology when providing space heating and hot water have been extracted from PHPP and used in SAP. However, it still needs to be verified whether this is possible in accordance with the SAP requirements.

12. Further discrepancies:
    a. Overshading factor for calculation of solar water heating
    b. Estimates for electricity for lighting
    c. Estimates for auxiliary electricity

3.3. Software implementation issues

1. Data extraction routine

   Dimensions and U-values of building elements could directly be extracted from PHPP as indicated by the orange cells in Figure 76. However, this step could only be quickly automated if the PHPP assessor uses default groups for building elements in the "Areas"-worksheet within PHPP. If the assessor chooses to create a separate group for building elements such as windows, a data extraction routine would be needed to check whether dimensions and U-values could be automatically extracted.. Note that window, door and rooflights areas (orange boxes) can be ported but not the rest of the building elements (grey boxes) due to the use of external dimensions.

Element	Gross area (m²)	Openings (m²)	Net area (m²)	U-value (W/m²K)	A*U (W/k)	κ-value (kJ/m².K)	A*κ (kJ/K)
Door			2.3	0.73	1.679		
Window			29.18	0.74280479	21.051399		
Roof window			1.69	1.35928994	2.2972		
Basement floor			0.00	0	0		0
Ground floor			74.48	0.12541677	9.34104135		0
Exposed floor					0		0
Basement wall	0	0	0	0	0		0
External wall	120.7	31.48	89.22	0.12605642	11.24675387		0
Roof	74.48	1.69	72.79	0.07122449	5.184430612		0
Total area of external elements (m²)			269.662475				
Party wall			0	0	0		0
Party floor			0				0
Party ceiling			0				0
Internal wall (area of both sides)			150				0
Internal floor			0				0
Internal ceiling			0				0

Figure 7: Screen grab from SAP spreadsheet showing the values highlighted in orange that can be extracted from PHPP, grey highlighted values are inputted by user and blue cells are locked, thus need no further input.

2. SAP collector orientation
   A smaller programming routine would be necessary to extract the solar collector deviation from North from the PHPP "SolarDHW"-worksheet and match it with the cardinal directions used within the SAP methodology.

3. Specific Fan Power for MV
   The extraction of specific fan power from PHPP could be laborious as a data link to the SAP Product Characteristics Database (PCDB) could be necessary.

3.4. SAP rating verification

The verification of SAP model outputs generated through the microscopic gap analysis (MIA) could not be entirely verified with bsap assessments in this work. In order to calculate a robust SAP rating for reliable comparison, the intended heating system control strategies for a dwelling must be known. However, there was ambiguity about the share between main heating systems and secondary systems where applicable. In the case of the Bridgend dwelling, there was not enough documentation to actually determine the control strategies between MVHR and air source heat pump in providing space heating respectively hot water. Also, the worksheet "HP Combi" was missing from the PHPP file.
Major model outputs of PHPP have been compared with SAP results obtained through the MIA approach. Estimates for ventilation heat loss, fabric heat loss, internal and solar gains as well as annual heat demand derived through SAP are in general higher than PHPP. Figure 8 shows the difference in these estimates related to the respective reference floor area averaged over all dwellings. The black bars represent standard deviation. The highest discrepancy is perceived for ventilation loss and internal gains estimates. However, annual heat demand shows smallest difference in average as gains and losses seem be nearly equally overestimated within SAP. The final difference in the estimated annual heat demand in SAP is in average about 2.8 kWh/m^2 higher than in PHPP with a standard deviation of 3.9 kWh/m^2. A detailed chart comprising the major model outputs per dwelling can be found in Appendix B.

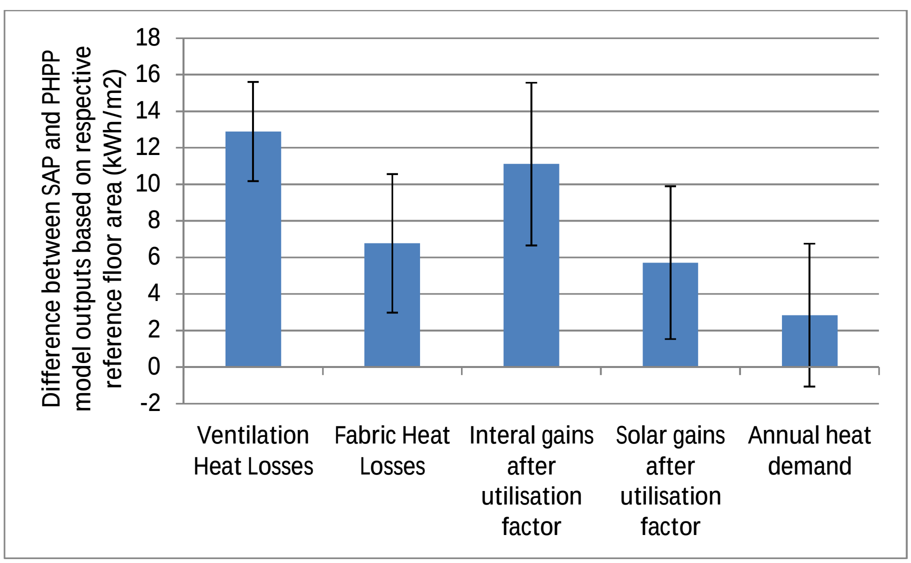

Figure 8: Difference between SAP and PHPP model outputs based on respective reference floor

4. Macroscopic Gap Analysis

Due to the discrepancies outlined in section 3, significant additional input would be necessary for an amended PHPP spreadsheet to produce a SAP rating. This can be particularly time-consuming if internal dimensions are not available or thermal bridges have to be thermally modelled in order to capture real values. For this reason, in the second analysis approach the data input stage was skipped and PHPP model outputs were fed into the SAP calculation at a later modelling step. The actual SAP results of this macroscopic gap analysis (MAA) approach were then compared with the results achieved through the microscopic gap analysis (MIA).

4.1. Analysis

Depending on the type of building services technology installed, the PHPP model equivalent for SAP “Space heating fuel” (step 211), “Fuel for water heating” (step 219) as well as “Electricity for lighting” (232) and “Electricity for pumps, fans and electric keep-hot (step 231) have been extracted. Table 2 gives an overview of each building services technology and application as the respective SAP modelling parameter and the PHPP equivalent.

Table 2: Overview of specific SAP modelling parameter and their PHPP equivalent for different building services technologies and applications

#	Technology & application	SAP energy requirement modelling parameter	PHPP equivalent
1	Boiler SH	Space heating fuel (SAP step 211)	Final Energy Demand Space Heating (“Boiler” worksheet)
2	Boiler DHW	Fuel for water heating (SAP step 219)	Final Energy Demand DHW (“Boiler” worksheet)
3	Heat pump SH	Space heating fuel (SAP step 211)	$= \text{Heat Supplied by Direct Electricity} + \frac{\text{Space Heat Supplied by HP}}{\text{Mittlere Arbeitszahl WP Heizung}} + \frac{\text{Winter Standby Heat Supplied by HP}}{\text{Mittlere Arbeitszahl WP Bereitschaft Winter}} + \frac{\text{Summer Standby Heat Supplied by HP}}{\text{Mittlere Arbeitszahl WP Bereitschaft Sommer}}$ (from “Compact” worksheet)
4	Heat Pump DHW	Fuel for water heating (SAP step 219)	$= \text{Final Energy Demand Heat Generation} - \text{PHPP equivalent \#3 from above}$ (from “Compact” worksheet)
5	Lighting	Electricity for lighting (SAP step 232)	Electricity Demand Lighting (“Electricity” worksheet)
6	Auxiliary electricity	Electricity for pumps, fans and electric keep-hot (SAP	Electricity Demand Total (“Aux Electricity” worksheet)

		step 231)	
7	MVHR SH	Space heating fuel (SAP step 211)	=Annual Heating Demand (“Monthly Method” worksheet) * 1.00 (efficiency of heating coil)
8	Heat Pump DHW (where “compact” worksheet missing!)	Fuel for water heating (SAP step 219)	= Total heat demand of DHW system (“DHW + Distribution” worksheet) / 2.3 (Average COP for summer and winter DHW provision)

The aim of the macroscopic gap analysis (MAA) approach was to reduce the amount of additional input parameters needed. In order to verify the reliability, SAP ratings from the MAA approach have been compared with previously ratings determined through microscopic gap analysis (MIA). Figure 97 shows the resulting SAP ratings for each dwelling obtained from both analysis approaches as well as the rating from the bsap assessment. Note that the bsap rating should undergo revision to obtain a robust SAP rating which could not be done within the project’s time schedule. This could be done by the project team in a following study. The absolute error between MIA and MAA approach is about 1.7 SAP rating points with a standard deviation of 2.3 points. The maximum error is 4.4 SAP rating points.

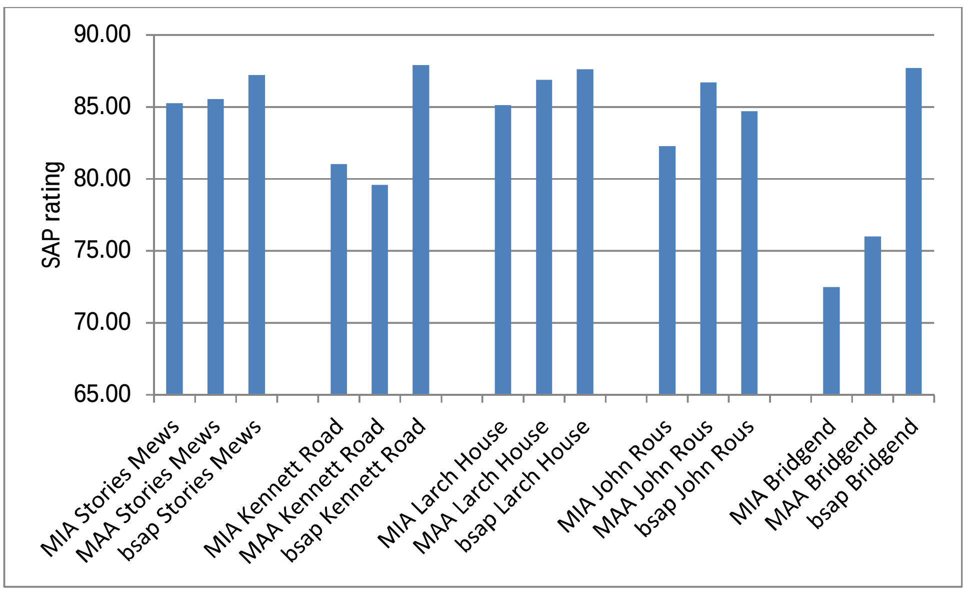

Figure 9: SAP rating produced through microscopic analysis (MIA), macroscopic analysis (MAA) and bsap assessment

In order to analyse the reason for the discrepancies between both method’s SAP rating results, the SAP energy requirement modelling parameter were compared. The annual fuel for space heating from the PHPP assessments for the examined dwellings is in average about 10 % lower than the values from the SAP methodology. When merely comparing absolute annual fuel for space heating from both models, there is little correlation. However, when relating these figures to the respective reference floor area a very strong linear correlation with a coefficient of determination $R^2 = 0.97$ was detected. This strong correlation suggests that despite many model discrepancies there could possibly be a proportional relation between both models. If these findings can be validated on a bigger sample size, many input parameters could be neglected and a calibration equation based on a regression model applied. That would save time and effort needed for additional user input. Figure 10 shows the relation between aforementioned modelling parameters.

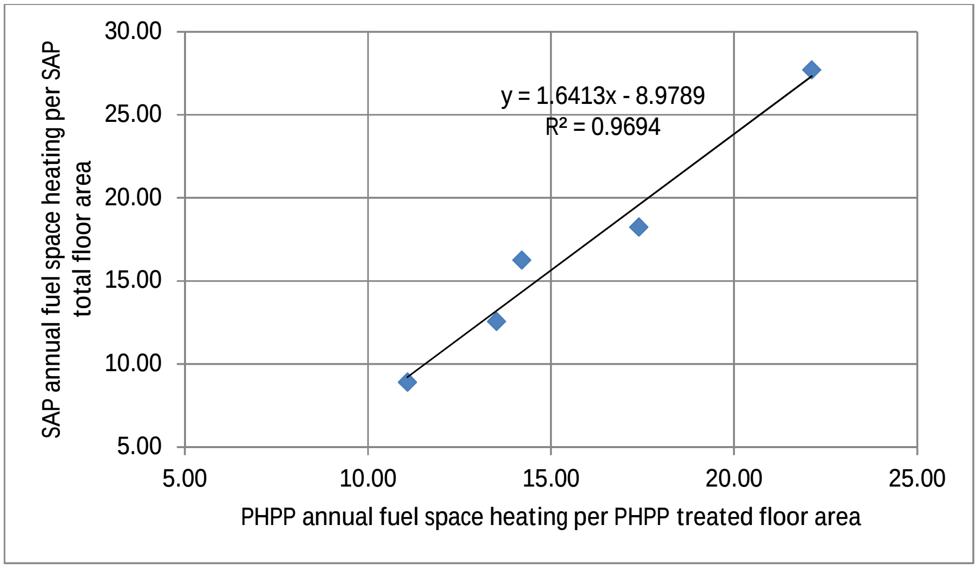

Figure 10: Relation between annual fuel space heating per respective reference floor area in both energy models

However, for other PHPP model outputs such a strong linear correlation could not be demonstrated. When applying a linear regression model to annual fuel for water heating per respective reference floor area $R^2 = 0.83$ was detected between PHPP and SAP (also refer to Figure 6). The same linear regression approach for annual electricity demand revealed an even smaller correlation of $R^2 = 0.56$.

However, it should be noted that the correlation of both models could be increased. When changing internal temperature in SAP from 21°C to 20°C the correlation coefficient of the linear model for the relation between annual fuel for space heating per reference area improved from $R^2 = 0.969$ to $R^2 = 0.972$. This shows, that the calibration equation could potentially be refined, if both models are studied more deeply.

5. Conclusion

The discrepancies between PHPP and SAP were investigated by carrying out a microscopic gap analysis focusing primarily on input parameters of both energy calculation methods as well as a macroscopic gap analysis which examined the feasibility of exporting model outputs from PHPP.

The microscopic gap analysis revealed for five Passivhaus dwellings that PHPP and SAP produce significantly varying model outputs with regards to heat losses and gains. However, it was ascertained that the resulting annual heat demand varies least with an average overestimation of about 2.8 kWh/m^2 of SAP over PHPP and a standard deviation of 3.9 kWh/m^2. These results have been produced under significant additional manual input of SAP modelling parameters such as internal dimensions, living area fraction, sheltered sides and thermal bridge values that could not be extracted from PHPP.

In order to decrease the manual input needed, the second approach focused on extracting more mature PHPP modelling parameters and importing them at a late SAP modelling step. Here, it could be shown that PHPP and SAP models predicts annual fuel for heating per reference floor area in a very similar way over the five dwellings examined. A linear regression model showed a considerably high correlation ($R^2 = 0.97$). Elevated correlation could also be shown when applying a linear regression model to PHPP and SAP annual fuel for water heating output parameter ($R^2 = 0.83$). Low correlation could be ascertained for annual electricity demand for lighting as well as annual auxiliary electricity demand which however would also need to be made available in order to generate a SAP rating.

Due to the high correlation of annual fuel for heating, the extracting as well as manual input of SAP modeling parameters could potentially be circumvented if further analysis can confirm the mathematical relation. Also, improvements to the bsap assessment ratings could be made by the current project team in order to validate the magnitude of discrepancy between the outcomes from this work and final results that would be eligible for compliance checks. Here, an extended investigation could be carried out after completing the technical documentation on the intended heating and hot water control strategy of the Passivhaus dwellings examined. Also, the allowed margin of error for SAP ratings produced for new built dwellings could be investigated. There exists already an allowed level of discrepancy which is +- 5 SAP rating points for existing dwellings stipulated by the DCLG Scheme Operating Requirements for Domestic Energy Assessors (DCLG, 2011).

Bibliography

DCLG. (2011, December). *DCLG Scheme Operating Requirements Associated with Domestic Energy Assessors and the Production of Energy Performance Certificates for Existing Dwellings*. Retrieved February 27, 2015, from http://www.bre.co.uk/filelibrary/accreditation/clg/DEA_SOR_V_3-0.pdf

Appendix A – Detailed comparison of modelling parameters for PHPP and SAP software tools

#	Factor	Description	PHPP	SAP	Porting feasibility from PHPP to SAP
1	**A, h**	Floor surface area, height	• Treated floor area ("TFA") used as reference area • One zone model	• Total Floor Area ("TFA") • Direct influence on modelling parameter such as hot water or lighting electricity demand • Fraction of living room floor area needed for modelling	Separate user input necessary
	Heat transmission through exterior walls and windows				
2	**k**	Heat capacity	-	• Used to calculate Thermal mass parameter (TMP) • Table 1e, p. 133	Can be ignored as TMP directly ported from PHPP
3	**TMP**	Thermal mass parameter	• Heat capacity per treated floor area	• Heat capacity per total floor area	Ported from PHPP and converted to kJ over SAP ToFA
4	$\mathbf{A}_{\mathbf{exterior}}$	External surface area of building elements to ambient air and ground	• External dimensions	• Internal dimensions, also called "Total Exposed Surface Area"	Automatically calculated based on dimensions of external surface building elements
5	$\mathbf{A}_{\mathbf{internal}}$	Walls within a building	• Not included	• Used for calculating Thermal Mass Parameter (TMP) (Table 1f, p.134)	Separate user input necessary; can be ignored
6	$\mathbf{A}_{\mathbf{window}}$	Window (glass door) and frame	• Separate input window and frame area necessary	• Frame factor according Table 6c • Window and door area refers to the total area of the openings, including frames	All input values available
7	$\mathbf{U}_{\mathbf{exterior}}$	Exterior wall and partition U-value	• User input or Passive House-certified	• Separate U-values against unheated space • BS EN ISO 6946 and BS EN ISO 13789.	All input values available
8	$\mathbf{U}_{\mathbf{roof}}$	Roof U-value	• User input or Passive House-certified	• Separate U-values against unheated space	All input values available
9	$\mathbf{U}_{\mathbf{window}}$	Window U-value	• Separate input window and frame U-	• **effective window U-value** used	All Input values available

			value or Passive House-certified glazing	(takes account of the assumed **use of curtains**): 1/[(1/U-value)+0.04] • Table 6e: Default U-values (W/m2K) for windows, doors and roof windows (U-value calculation in Annex F of BS EN ISO 10077-1)	
10	**U_{ground}**	Floor U-value	• PHPP procedure according to EN 6946 with rated values of the conductivity	• calculation BS EN ISO 13370, in section A3 of the CIBSE Guide A or in the Approved Document ‘Basements for dwellings	All Input values available
11	**U_{door}**	Doors U-values	• Manual input, worksheet “Areas”		All input values available
12	**FX**	Temperature correction factor depending on adjacent air or ground temperature	A = 1.0 B ≈ 0.5 (f=(climate) Manual (p. 40)	U-values are directly changed when element towards unheated space etc. (p.14)	Included in U-value calculations
13	**$theta_{int}$**	Internal temperature	• default=20°C or manual	• Calculation of mean internal temperature is based on heating patterns (Table 9, p.157), HLP and 21°C living room temperature	SAP mean internal temperature more complicated; should not be replaced by PHPP temperature directly
14	**$theta_{ext}$**	External temperature	• Climate data base	• Done with UK average weather for Part L compliance, regional weather data used for EPC and cooling calculation	Reference to UK average or regional weather
	Thermal bridging				
15	**Ψ**	Linear thermal transmittance	Tool for calculation available (p.51)	Based on 1) Approved Design Details, 2) BR 497, BRE IP 1/06, 3) Equation (K2) Table K1, p. 78 If details of the thermal bridges are not known, use HTB = $y^*\sum A_{exp}$	Major discrepancy in the methodology: separate input necessary
16	**L**	Length	Length of Thermal bridge? (tbc)	Length of Thermal bridge? (tbc)	Major discrepancy in the methodology: separate input necessary
	Ventilation and infiltration heat losses				
17	**Air change rate**		Measured on site and directly reported	SAP uses q_{50}	All inputs available, minor

	from press. test		in PHPP	According BS EN 13829	calculations necessary (uses dwelling volume and total external area)
18	**Design air flow rate (maximum)**		Calculated based on indicative values	Calculated based on number and type of openings	Could be amended based on PHPP values
19	**Infiltration air change rate**		Separately calculated	Air change rate for mechanical ventilation systems is based on different assumptions	Could be amended based on PHPP values
20	**Ventilation Heat Loss**		Calculated for the MVHR system	0.33*effective air change rate * V $(38)_m$	Could be amended based on PHPP values
	Solar heat gains				
21	**Area**	Area of rough window opening	Available in window sheet	Area of rough window opening input directly in SAP	All inputs available
22	**Solar Flux**	W/m^2		Solar Flux (74)-(82)	All inputs available
23	**g_T**	Solar transmittance window	Available in window sheet (g-value)	(74)-(82)	All inputs available
24	**FF**	Frame factor for window	Glazed fraction per window (worksheet “window”)	Frame Factor(FF) (Table 6c)	All inputs available
25	**Z**	Summer access factor	Overhang width unknown	Solar and light access factors (table 6d) Overshading (Heavy, More than average , Average or unknown, Very little) Zsummer = Zblinds (Z + Zoverhangs – 1) “wide overhangs” = overhang is at least twice as wide as the window “normal overhangs” = overhang is less than twice as wide as the window	Summer overheating not a critical issue for this assessment SAP lookup tables and overhang width calculated separately
	Internal heat gains				
26	**Metabolic gains**		See “IHG” spreadsheet = (num people within the envelope area)*(norm consumption = 80)*(utilisation factor)*frequency Can also be found in “electricity” spreadsheet	ƒ(TFA) if TFA > 13.9: N = 1 + 1.76 ´ [1-exp (-0.000349 ´ (TFA-13.9)²)] + 0.0013 ´ (TFA-13.9) if TFA £ 13.9: N = 1	See #1

27	**Appliances**		See “IHG” spreadsheet Includes (among others) dishwashing, clothes washing and drying, refrigerating… Can also be found in “electricity” spreadsheet	ƒ(TFA) Included in heat gains but not in energy use/CO2 emissions	See #1
28	**Lighting**		Lighting energy is modelled as a whole and includes both fixed and plug-in lighting.	GL,m = $E_{L,m}$ * 0.85 * 1000 /(24 * n_m) $E_{L,m}$ = ƒ(TFA, lookup table) Includes movable and fixed lighting in indicative factor Note: Movable lights included in gains, but not in energy use/CO2 emissions	See #1
29	**Cooking**		See “IHG” spreadsheet Depends of the number of persons living in the house Can also be found in “electricity” spreadsheet	ƒ(TFA) Used for gains but not for energy use/CO2 emissions	See #1
30	**Water heating**		See #37 Depends of the length of pipes and their insulation	ƒ($(65)_m$) “heat gains from water heating”	See “water heating energy requirement”
31	**Losses**			ƒ(TFA)	See #1
32	**Pumps and fans**			ƒ(specific fan power, in-use factor, dwelling volume)	Input available
	Water heating energy requirement				
33	**demand for hot water**		Depends on the number on persons in the dwelling See spreadsheet “DHW=Distribution”	ƒ(TFA, Table 1b, Table 1c, Table 1d)	Included in calculations See #1
34	**Heating system**		Boiler / Heat pump / district heating See spreadsheet “PE value” for a general overview and “boiler”, “district heating” and “HP ground” for details	See p 22. SAP consider the possibility of multiple heating system, which can be ignored for this work	Manual input necessary for most of the related cells (see spreadsheet)
35	**Source of energy**	Additional source of energy that can be subtracted for the amount of energy needed to	”Solar DHW” spreadsheet. It seems that PHPP does not take WWHRS into account	Solar or WWHRS	Input available

		heat water			
36	**Standing loss thermal storages**		See “DHW=Distribution” spreadsheet. Losses are calculated as accurately as possible, storage is taken into account, but the length of pipes is also used contrary to SAP Also note that PHPP takes into account the fact that these heat loss through storage and distribution can partly be considered as “internal gains” (see #31) “Secondary Calculation Efficiency of Heat Generation from Wood:” “Boiler” worksheet	ƒ(Cylinder Volume)	Included in calculations
37	**Combi boiler or system boiler**		DHW storage in spreadsheet “Solar DHW”	Primary circuit losses, combi boiler losses are calculated in Table 3a, 3b or 3c , ƒ(insulated pipework fraction, rejected energy proportion r1, loss factor F1)	Information can be retrieved from PHPP
	Space heating energy requirement				
38	**T_i**	Mean internal temperature	Same temperature in the entire dwelling (**20°C** is the default value, must not be changed unless justified)	ƒ(Temperature adjustment based on heating system and controls, Table 4e), Step (93)	Check #42, #44, #45, See also #13
39	**Utilisation factor for heating**		See “boiler” or “district heating” spreadsheet (depending on the type of heating)	Calculation based on TMP Table 9a, p.157	See #3
	Space cooling requirement				
40	**Space cooling demand**		Refer to “Cooling Load” spreadsheet	Standardised cooling pattern of 6 hours/day operation (cooling when above 25 Centigrade). Table 10a and 10b	See #41
41	**Utilisation factor for cooling**		“Daily internal temperature stroke” in summer and cooling worksheet from version 8.5!!!	Table 10a	See #3
	Energy requirements				
42	**Boiler**		Worksheet “boiler” Cell F19	Type of heating generation and controls,	See #13

				Table 4e: GROUP 1: BOILER SYSTEMS WITH RADIATORS OR UNDERFLOOR HEATING (and micro-CHP)	
43	**Boiler efficiency**		Probably “Nutzungsgrad” (Heating worksheet, T112) Worksheet “PE Value” F68	See table 4a	Manufacturer specs vs. lookup table
44	**Heat pumps**	Mainly SAP criteria	Worksheet “HP” Control strategy in HP worksheet	Table 4e: GROUP 2: HEAT PUMPS WITH RADIATORS OR UNDERFLOOR HEATING	All input available
45	**District heating**		Worksheet “District Heating”	Table 4e: Heating system controls, GROUP 3: COMMUNITY HEATING SCHEMES	?
46	**Cooling System Efficiency Ratio**			ƒ(Energy label) Table 10c	?
47	**Responsiveness of heating system**		No information on radiators or underfloor heating	Table 4a	Could be ignored
48	**Electricity for pumps, fans and electric keep-hot**			Table 4f, for Mechanical extract ventilation SFP and IUF needed	?
49	**Electricity generated by PV**		Worksheet “PV”	Ƒ=(0.8 * kWp * S * Z_{PV})	“Overshading Factor” entered manually in SAP
50	**Electricity generated on-site**	Micro-CHP, Wind turbine, hydro electric generator	Not included IN PHPP	Included	Manual input necessary for SAP
	MVHR				
51	**MVHR**		Different Passivhaus certified MVHR available. It is possible to specify with manual inputs See “Ventilation” spreadsheet for more details	In SAP, in use factors are applied to the specific fan power and heat exchanger efficiency to allow for installation inefficiencies compared to laboratory test conditions of units. If MVHR not listed in SAP Q/PCDB then default	Different methodology used to determine efficiency including energy recovery

				figures used.	
52	**Heat recovery efficiency**		See “Ventilation” spreadsheet	(23c)	All inputs available
	Miscellaneous.				
53	**Fuel price**		-	See table 12, get fuel type from PHPP	All inputs available; connect to lookup table
54	**Property type**		-	Form / detach, number of room, number of heated habitable rooms	Not needed for calculation
55	**Electricity tariff**		Could not find the information in PHPP	Influences the final result	Connect with SAP lookup table
56	**Shelter factor**	How the dwelling is protected against wind	Wind protection factor e and f according to ISO 13790	Number of sheltered sides, impacting adjusted infiltration rate -> space heating requirement	Manual input necessary
57	**Climate data**		Climate data changes according to regions. As accurate as possible for the site chosen.	SAP now contains regional climate data, which is used for some calculations, including energy use, costs and overheating risk. However, average UK data along with other normalised factors are still used for the calculation of the Fabric Energy Efficiency (FEE) parameter, TER, DER, SAP and EI ratings for comparability across the whole country.	All input available

Appendix B – Annual modelled heat losses and gains in kWh per m2