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A COMPARISON OF THE UK STANDARD ASSESSMENT PROCEDURE (SAP) AND DETAILED SIMULATION OF BUILDING-INTEGRATED RENEWABLE ENERGY SYSTEMS

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ABSTRACT

The drive to reduce UK Carbon Emissions directly associated with dwellings and to achieve a zero carbon home dictates that Renewable Energy Technologies will have an increasingly large role in the built environment. Created by the Building Research Establishment (BRE), the Standard Assessment Procedure (SAP) is the UK Government's recommended method of assessing the energy ratings of dwellings.

This paper presents an evaluation of the advantage given to SAP ratings by the domestic installation of typical Photovoltaic (PV) and Solar Domestic Hot Water (SDHW) systems in the UK. Comparable PV and SDHW systems will also be simulated with more detailed modelling packages.

Results suggest that calculation variances can exist between the SAP methodology and detailed simulation methods, especially for higher performance systems that deviate from the default efficiency parameters.

KEYWORDS

Standard Assessment Procedure (SAP), PV, Solar Domestic Hot Water (SDHW), PVSyst, TRNSYS

INTRODUCTION

SAP is the UK government's Standard Assessment Procedure to calculate a building's energy efficiency and carbon emissions. SAP 2005 is used to demonstrate dwellings compliance under the Part L (England and Wales), Section 6 (Scotland) and Part F (Northern Ireland) building regulations. SAP is also the UK governments selected National Calculation Methodology (NCM) for the assessment of dwellings under the European Directive on the Energy Performance of Buildings (EPBD). In addition to this verification of the SAP methodology, SAP certification has been required on all new UK dwellings since 1995 (SAVE, 2001). Whenever a UK dwelling is constructed, leased or sold, the SAP methodology must be employed to calculate a rating for Energy Efficiency and Environmental Impact.

Recent research (Syed et al 2007) clarifies the benefit that PV offers to the residential sector; even in northerly situated countries. Domestic and distributed

PV systems account for more than 75% of the 7.8 GW_p installed in IEA PVPS countries at the end of 2007 (IEA-PVPS, 2007). Domestic solar thermal applications represent the biggest portion of installed solar heat capacity (128 GW_{th}) and produced energy (77 TWh) (Weiss et al., 2008). This is especially important given that recent studies demonstrate that a third of total domestic energy load of a new dwelling can be attributed to water heating (Ren et al 2007). This underscores the importance for building regulations and energy rating procedures such as SAP to represent accurately the benefits of solar thermal and photovoltaic systems.

Because of its key role in the regulatory framework for dwellings in the UK, SAP can play a significant role in the establishment of innovative measures and technologies. Some manufacturers have questioned the SAP methodology (Contract Journal, 2006).

SAP is based on the Building Research Establishment Domestic Energy Model-12 (Anderson et al, 2001). The SAP methodology used to assess the energy performance of buildings is based on simple physical equations and empirical evidence; this is also true for the assessment of building-integrated solar thermal and photovoltaic systems. The UK government has recognised the requirement for SAP to accurately model low and zero carbon technologies (DCLG, 2007). The SAP methodology has been compared to detailed simulation for low-energy buildings (Cooper, 2008). This study found discrepancies for low energy dwellings and the benefits of some passive solar features. To the authors knowledge there is no research which directly compares the SAP methodology for PV and SDHW with more detailed assessment methods. This paper seeks to address this situation by investigating the comparison of SAP methodology calculations with more detailed assessment methods.

OBJECTIVE

This paper aims to compare the PV and SDHW calculations in the SAP methodology with more detailed methods of analysis. It is split in three main sections. The first section will detail a series of Case Studies where comparisons are made between the SAP results for PV and a more detailed numerical simulation of various domestically installed PV

systems. The second will measure a standard UK installation of a SDHW system in both SAP and a more detailed analysis. The third will preliminarily assess and simulate a case study of a BRE Innovation Park dwelling incorporating both PV and SDHW.

SOFTWARE TOOLS

In-house BRE SAP software was used to derive a SAP rating for a defined Standard Test Case building. SAP software was used for the calculation of SAP ratings and Carbon Dioxide emissions according to the SAP worksheet. Commercially available BRE approved SAP 2005 calculation tools are available. SAP calculates ratings for Energy Efficiency (EE) and Environmental Impact Rating (EIR) in the range of 1 to 100. The higher the score, the more energy efficient the home is and the less impact the home will have on the environment. The ratings are grouped into alphabetised bandings, as detailed in Figure 1; 1-20=G, 21-38=F, 39-54=E, 55-68=D, 69-80=C, 81-91=B, 92-100=A.
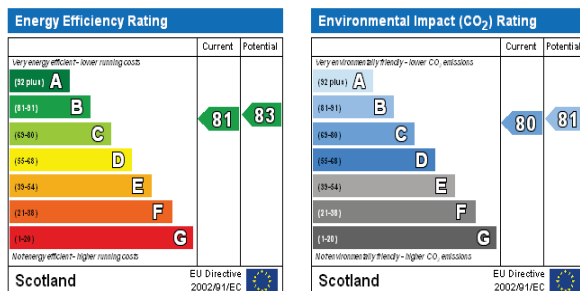

Figure 1 Sample SAP derived Energy Efficiency and Environmental Impact Ratings

For the sake of brevity, only EE ratings are discussed in this text and they are referred to as "SAP ratings".

PVSyst is PC oriented software which can be used to simulate, analyse and study various PV systems. For the purposes of this research, PVSyst was employed as the detailed simulation tool to model building integrated PV systems. PVSyst is an assessment and benchmarking tool used by PV industry professionals (Lyle, 2009) and PV researchers (Wittchen, 2003).

The TRNSYS 16 Simulation Engine was selected as the detailed SDHW modelling tool for this paper. TRNSYS is referenced in European Standards, such as EU ENV-12977-2, for Solar Thermal Systems. Additionally TRNSYS was selected as the reference tool in several projects of the International Energy Agency's Solar Heating and Cooling Programme (Perers and Bales, 2002).

METHODOLOGY

A Standard Test Case (STC) dwelling was initially modelled in SAP. The STC is detached dwelling with dimensions detailed in Table 1.

SAP v9.82 was used to produce the SAP ratings. The SAP rating for the Standard Test Case (STC) dwelling was calculated with the SAP software. A small detached house with a total floor area of 104m[2]

was modelled in SAP. This house is part of a set of BRE developed archetypes to represent the existing building stock. It achieves a SAP rating of C72.

Table 1: STC Dwelling SAP Input Listings

Element	Gross area [m²]	Openings [m²]	Net area [m²]	U value [W/m²K]
Ground floor			52.00	0.22
First floor			52.00	0.22
Walls	143.00	24.50	118.50	0.30
Roof	52.00	0.25	51.75	0.16
Doors			7.60	3.00
Windows			16.90	2.10
Roof windows			0.25	2.30

PV SIMULATION

The modelled PV system has a peak power of 2 kWp, which is a typical value for a commonly installed PV system in the UK (Energy Saving Trust, 2009). A 2kWp system could provide approximately 50% of the average household's electricity; based upon a typical annual electricity consumption of 2500kWh for a three bed-roomed property (Bahaj and James, 2006). SAP does not allow for PV details such as make and model to be input. SAP requires kWp, Orientation, Pitch and Overshading. The addition of 2kWp PV improved the SAP rating from C72 to B81. The SAP calculations to obtain the amount of generated electricity are described below.

SAP calculation to determine kWh/year - PV

In SAP v9.82 the following calculation is used to determine the available energy at inverter output in kWh/year produced by a PV system:

$0.80 * kWp * S * Z_{PV}$

Where:

0.80 – SAP empirical factor for PV

S – Annual solar radiation

Z_{PV} – Overshading factor

Details from SAP Table H2 (Table 2) are used in SAP for the purposes of calculating the system output energy of a Building Integrated PV system.

Table 2
SAP Table H2 – Annual Solar Radiation, kWh/m²

Tilt of Collector	Orientation of Collector				
	South	SE/SW	E/W	NE/NW	North
Horizontal	933				
30°	1042	997	886	962	709
45°	1023	968	829	666	621
60°	960	900	753	580	485
Vertical	724	684	565	427	360

These values are tabulated for Sheffield, which was selected by SAP designers as the nominal centre of the UK. Using one reference weather location allows for dwellings throughout the UK to be compared.

For a 2kWp system installed in the STC, south facing with no overshading, the calculated available energy at the inverter output is 1667 kWh/year.

Use of PVSyst to determine kWh/year

To compare the SAP results directly with the results from PVSyst, the location of Sheffield, UK was taken with a PV system of 2kWp. Weather data for Sheffield, UK is not included with PVSyst by default but it was imported into the software, using a data file from Meteonorm (Meteotest, 2009). An SMA Sunny Boy 2100TL 2.0kW inverter was selected with an array of 10 Kyocera KC 200GHT-2 Polycrystalline 200Wp PV modules, to represent components typically installed in the UK (Lyle, 2009). The modules were connected according to the voltage requirements of the inverter and all default PVSyst options were kept. No shading was assumed. The PVSyst-calculated output was 1637 kWh/year, which can be directly compared to the SAP figure of 1667 kWh/year. The 2% difference between SAP and PVSyst results had no significant effect to the SAP rating, which remained at B81 for the STC.

Effect of PV components on SAP rating

SAP allows for the modelling of a generic PV system based upon kWp. PVSyst allows for different PV components systems to be modelled and provides an extensive database of modules and inverters available on the market.

Table 3: Available Energy at Inverter Output

Method	PV panel and material	Inverter	Yield [kWh/y]	SAP rating
PVSyst	Sulfurcell SGC50 HV-F (CIS)	SMA Sunny-Boy 2100GT	1824	B82
SAP	N/A	N/A	1667	B81
PVSyst	Kyocera GHT200 (Polycrystalline)	SMA Sunny-Boy 2100GT	1637	B81
PVSyst	Eurener PEPV 200 (Polycryst.)	Suntechnics STW1900	1514	C80

A selection of 2kWp systems, for a Sheffield, UK weather location, with a 30° angle and South Azimuth, were modelled in PVSyst - to match the size of the system modelled in SAP, to determine if PV components had any effect on SAP rating. Table 3 highlights the variability of available energy (kWh/year) from a selection of 2kWp rated systems. Table 3 also highlights that different selections of PV panel and inverter can lead to a variation of the PV output of approximately +/- 10% without altering any of the assumptions. The variation in PV Output can account for an adjustment to the SAP rating of +/- 1.

SAP results are constant with typical values for PV over the range of ratings for different PV systems.

Effect of Weather Location

The most typical PV system was then modelled in PVSyst for a variety of UK locations, to determine the effect on SAP ratings. The location of Sheffield was selected to match the location of SAP. Efford

was selected as a reference point for the south of England. Eskdalemuir was selected as a reference weather location for Southern Scotland and the North of England. The three weather data files used in PVSyst were generated by Meteonorm to ensure consistency. The two additional weather stations were selected because of the availability of measured solar radiation, which improves the quality of Meteonorm-generated weather data files.

Table 4: Results for several locations based upon 2kWp South Facing PV system at 30°

Calculation methodology	Location	Inverter output [kWh/y]	SAP rating
PVSyst	Efford	1983	B83
SAP	Sheffield	1667	B81
PVSyst	Sheffield	1637	B81
PVSyst	Eskdalemuir	1480	B80

Table 4 details available energy at Inverter Output in kWh/year: the Eskdalemuir location shows a reduction in over 187kWh/year as calculated by PVSyst (-11%), which would be equivalent to a SAP rating of B80. The Efford location highlights an improvement of 316kWh/year over SAP (+19%), resulting in a SAP rating of B83. SAP can be used to rank energy saving investments and a small difference of one or two marks in SAP ratings could in fact be significant. In this respect, it could be argued that PV systems do not get the credit they deserve in some locations (e.g. South England) while their savings are overestimated for other locations (e.g. Scotland).

Combined effect of PV systems and Weather data

A combination of varying PV systems and UK Weather locations were modelled in PVSyst to establish the effect that this combination would have on kWh/year and SAP rating. Table 5 highlights that, in comparison to SAP default of 1667kWh/year B81, +33% kWh/year and +3 SAP points variation can be demonstrated from the 2kWp Sulfurcell system installed in Efford. The 2kWp Eurener system modelled in Eskdalemuir highlights a -18% kWh/year and -1 SAP point variation.

Table 5: Results for several locations based upon 2kWp South Facing PV system at 30°

Method and location	PV panel and material	Inverter	Yield [kWh/y]	SAP rating
PVSyst (Efford)	Sulfurc. SGC50 HV-F (CIS)	SMA Sunny-Boy 2100GT	2183	B84
PVSyst (Sheffield)	Sulfurc. SGC50 HV-F (CIS)	SMA Sunny-Boy 2100GT	1824	B82
SAP (Sheffield)	N/A	N/A	1667	B81
PVSyst (Sheffield)	Kyoc. GHT200 (Polycrystalline)	SMA Sunny-Boy 2100GT	1637	B81
PVSyst (Sheffield)	Eurener PEPV 200 (Polycryst.)	Suntechnics STW1900	1514	C80
PVSyst (Eskdal.)	Eurener PEPV 200 (Polycryst.)	Suntechnics STW1900	1363	C80

Other differences between SAP and PVSyst

Results for a slope of 30° and an azimuth of due South have been discussed so far. Other calculations were performed for different slopes and azimuths, combining different locations and different system components. These are not presented in detail due to space constraints. The differences calculated between SAP values for different orientations are generally within 10% of the differences calculated by PVSyst for the same orientations. SAP neglects the impact of incidence angle and seems to overestimate the performance for unfavourable orientations (e.g. vertical West) and underestimate the performance for favourable orientations (e.g. 60° South).

SDHW SIMULATION

A typically installed SDHW system in the UK was taken to be a Glazed Flat Panel with an aperture of $5m^2$ (Energy Saving Trust, 2009), south facing, with a 300 L dual coil domestic hot water cylinder. SAP does not allow for SDHW details such as make and model be inputted. SAP requires Aperture Area, Collector Type (Evacuated Tube, Flat Panel or Unglazed), Collector Efficiency (zero-loss collector efficiency and linear heat loss coefficient of collector, W/m^2K), Roof Orientation, Pitch and overshading. The SAP calculations to obtain the solar input are detailed below.

SAP v9.82 calculation to determine contribution to domestic hot water

$$Q_s = S * Z_{panel} * A_{ap} * \eta_0 * UF * f(a_1/\eta_0) * f(V_{eff}/V_d)$$

Where:

Q_s	= solar input, kWh/year
S	= total solar radiation on collector, kWh/m²/year (from SAP Table H2)
Z_{panel}	= overshading factor for the solar panel
A_{ap}	= aperture area of collector, m²
η_0	= zero-loss collector efficiency
UF	= utilisation factor
a_1	= linear heat loss coefficient of collector, W/m²K (from SAP default values or certified performance test)
$f(a_1/\eta_0)$	= collector performance factor = $0.87 - 0.034 (a_1/\eta_0) + 0.0006 (a_1/\eta_0)^2$
$Veff$	= effective solar volume, litres
Vd	= daily hot water demand, litres (from SAP tabulated data versus floor area)

$f(V_{eff}/V_d)$ = solar storage volume factor = $1.0 + 0.2 \ln(V_{eff}/V_d)$ subject to $f(V_{eff}/V_d) <= 1.0$

Q_s details a dwelling's kWh usage saved due to the installation of a SDHW system. The required auxiliary energy is then calculated taking into account the energy in hot water, the distribution losses and the tank losses. This auxiliary energy is then used in the main SAP worksheet where it is combined with the energy used for space heating, etc. to obtain the SAP rating. SAP also adds a fixed amount of 75kWh/y to the electricity usage of a house to account for the energy required by the solar thermal circulating pump.

For our Standard Test Case dwelling with the typical SDHW system described above, SAP provides default efficiency values for solar collectors in Table H1 (see Table 6 below). It can be noted that the default efficiency for glazed collectors (flat-plate and evacuated tube) is significantly lower than values recommended by the IEA-SHC programme based on collector tests (IEA-SHC, 2004). The first-order loss coefficient (a1) in Table 6 is more than double of typical IEA values, so that the efficiency of evacuated tube collectors under nominal operations specified in the same IEA document is 0.72 for the IEA typical, and 0.51 for the SAP default.

Table 6
SAP Table H1 - Default Collector Parameters

Collector Type	η_0	a_1	Ratio of aperture area to gross area
Evacuated Tube	0.6	3	0.72
Flat Plate, Glazed	0.75	6	0.90
Unglazed	0.9	20	1.00

Hot water energy requirements are related to the total floor area (TFA) of a dwelling. The TFA of the STC dwelling is $104m^2$. SAP Table 1 (Hot Water Energy Requirements) states that a dwelling with a $104m^2$ TFA would have a hot water usage of 119 litres per day, with an Energy Content of Heated Water (including distribution losses) of 2532 kWh/year. One key parameter is the loss coefficient of the hot water storage tank. In this study, it was assumed that the storage tank is at the upper limit of band "B" in standard EN15332, i.e. 2.49 kWh per 24 h for a 300 L tank. SAP-calculated output of the auxiliary water heater is 3437 kWh without a solar system, and 1924 kWh with the system described above (assuming the same 300 L storage tank is used in both cases). The calculated solar input is 1186 kWh and the losses in the 300 L tank drop from 545 kWh/y to 218 kWh/y. The SAP rating for the STC dwelling increases from C72 to C74.

Use of TRNSYS to determine kWh/year

TRNSYS allows the detailed modelling of a solar thermal system. An identical Flat Plate Collector system to that modelled in the STC was modelled in TRNSYS, using standard components from the TESS libraries (TESS, 2007). The TRNSYS simulation was setup to represent a typical good practice system. The flowrate is set to 50 L/h-m² with a 25 W pump, solar primary piping losses are set to 0.2 W/m-K. The domestic hot water profile is set to three draw-offs per day at 7am, 12pm and 5pm, with respectively 40%, 20% and 40% of the daily volume. The tank loss coefficient was set to the same value as in SAP, i.e. 2.49 kWh per 24 h. The loss coefficient in EN15332 is calculated for standardised temperatures (room = 20 °C, hot water = 65 °C) and SAP applies a

"temperature factor" of 0.6 to this loss coefficient. This would result in a very large discrepancy between SAP storage losses and TRNSYS storage losses if a hot water temperature of 65 °C was assumed. The TRNSYS simulation therefore assumes a hot water setpoint of 50 °C with a thermostatic valve bringing it down to 45 °C, and the daily load is adapted (170 L per day at 45 °C). The mains water temperature is 10 °C in average and varies by +/- 2.6 °C over the year. SAP and TRNSYS results are presented in Table 7.

Table 7
SDHW results overview

Solar collector	Location	Slope and azimuth	Solar input [kWh]		Water heater output [kWh]	
			SAP	TRN SYS	SAP	TRN SYS
SAP FP	Sheffield	30°, S	1186	1461	1924	1782
IEA Flat-Plate	Sheffield	30°, S	1395	1840	1714	1488
	Eskdalem	30°, S		1635		1647
	Efford	30°, S		2237		1191
SAP ET	Sheffield	30°, S	1241	1548	1869	1714
IEA Evacuated tube	Sheffield	30°, S	1530	2246	1580	1220
	Efford	30°, S		2626		965
	Sheffield	45°, S	1521	2344	1588	1141
	Sheffield	60°, S	1493	2371	1617	1110
	Sheffield	90°, S	1353	2184	1757	1199

TRNSYS results for the typical system described above, using SAP default efficiency parameters (η_0 = 0.75 and a_1 = 6W/m²-K), show a solar input of 1461 kWh/y and a value of 1782 kWh for the water heater output. It is interesting to note that the solar input is 23% higher than the SAP value but the water heater output is only 7% lower, because of different tank losses (357 kWh/y, i.e. 64% higher than the SAP value).

As described above for the PV simulations, it is possible to calculate the SAP rating obtained if the SDHW system was simulated in TRNSYS and that result utilised in the main SAP calculation. The water heater output calculated in TRNSYS is then used rather than the solar input, so that the different tank losses are taken into account. For the system described above, the SAP rating is unchanged at C74.

Effect of Collector parameters

SAP calculations and TRNSYS simulations were performed for collectors with parameters matching the typical values recommended by IEA (IEA-SHC, 2004). For glazed flat-plate collectors, the TRNSYS solar input is 32% higher than the SAP value, while the water heater output is 13% lower. For IEA typical evacuated tube collectors, TRNSYS predicts a 47% higher solar input and 23% lower water heater output. For both IEA typical collectors, the SAP rating increases from C74 to C75 if TRNSYS results are utilised in the SAP calculation.

Another interesting comparison is between a SAP calculation using the default SAP efficiency for evacuated tubes and a TRNSYS simulation using default IEA parameters for evacuated tubes. The latter gives a solar input 81% higher and a water heater output 35% lower than SAP calculations with default parameters for evacuated tubes. The SAP rating would be C75 instead of C74. This underlines the importance of using certified performance data in SAP rather than default values.

Effect of SDHW Weather Location

TRNSYS was used to simulate an identical system (system described above with typical IEA flat-plate performance) for a number of UK weather locations. Figures were calculated for a northerly and southerly location in the UK, as in the PV section.

The TRNSYS calculated values for solar input are 17% higher in Eskdalemuir and 60% higher in Efford, with a water heater output respectively 4% lower and 31% lower. The equivalent SAP rating would increase from C74 to C75 in Sheffield and Efford but remain Eskdalemuir.

Other differences between SAP and TRNSYS

Simulations were performed for different slope and azimuth angles, different locations and different collector parameters. A selection of these results is shown in Table 7. The most striking differences appear for high performance collectors such as the IEA-typical evacuated tubes, for which differences in solar input reach +72% (in Efford) and differences in water heater output reach -39%, leading to a different SAP rating (C75).

Another interesting conclusion from these results is that the influence of the collector slope is different in SAP and TRNSYS. Systems with a higher slope than 30° always perform worse in SAP, while the optimum slope in TRNSYS is 45° for maximum solar input and 60° for minimum water heater output. A higher tilt angle will increase the performance of SDHW systems in winter while the performance in summer will be affected less, especially for systems with a high solar fraction. This increases the match between supply and demand, and is not taken into account in SAP. For Sheffield, the difference in solar input between TRNSYS and SAP moves from 47% to 59% for IEA evacuated tubes when the slope goes from 30° to 60° (South-facing). Both systems have a rating of C74 in SAP and C75 when TRNSYS results are taken into account.

Finally, using a rated pump power of 25 W the TRNSYS-calculated pumping energy was between 50% and 75% of the SAP value (which is set to 75 kWh in all configurations).

BRE INNOVATION PARK CASE STUDY

The BRE Innovation Park (based at BRE, Garston, UK) allows companies to construct homes of the future, demonstrating implementations of Renewables and Modern Methods of Construction.

Stewart Milne Sigma Home

A preliminary study of the Sigma Home was conducted. The dwelling has a total floor area of 116 m² and is equipped with PV and SDHW systems which will be modelled as part of this research [the Stewart Milne Sigma Home also has a Wind Turbine installation, which is not considered here].

Table 8: Sigma House SAP Input Listings

Element	Gross Area (m²)	Openings (m²)	Net Area (m²)	U-Value (W/m²K)
Ground Floor			33.13	0.13
Exposed Floor	4.00		4.00	0.13
Walls	174.79	44.35	130.44	0.15
Roof (1)	21.02		21.02	0.13
Roof (2)	16.17		16.17	0.11
Doors			1.89	2.00
Windows (1)			42.46	0.70
Windows (2)				1.40
Roof Windows			0.25	2.30

Discussions with Stewart Milne and the project development company (RD Energy Solutions Ltd) who sourced the Renewables allowed for access to plans of the dwelling and installed Renewables. The SIGMA home was modelled with our best understanding of the data received (Lyle, 2009 and Dalgarno, 2009). One main simplification is that existing shading is ignored both in the SAP assessment and in the detailed modelling.

SAP modelling of SIGMA Home

As detailed in Table 8, the Sigma Home was modelled in SAP and produced a SAP Rating of C73.

SIGMA House + PV modelled in SAP

The installation of PV at the Stewart Milne Sigma House utilises Kyocera KC200GHT PV Panels, 4.8kWp installed on an east facing low pitch (10°) and 1.2kWp installed on the south facing vertical façade; with a Mastervolt QS6400 inverter. The east facing PV pitch was taken as 0° (i.e. horizontal) with no overshading in SAP for the purposes of this preliminary study (PVSyst uses the correct pitch).

4.8kWp of horizontal PV and 1.2kWp of vertical PVs have been inputted into SAP. The area of vertical PVs were adjusted to the equivalent kWp if they were 0° using SAP Table H2 (1.2 x 724 / 933 = 0.93kWp). In total, 5.73 kWp of horizontal PVs were entered into SAP, with very little overshading selected.

SAP calculation to determine kWh/year - PV

5.73 kWp of horizontal PV with no overshading will generate 4278 kWh/year (0.80 * 5.73 * 933 * 1.0). The effect of the installation of this PV array is to increase the SAP Rating to A94.

SIGMA Home PV modelled in PVSyst

Matching the installation at the SIGMA home, a 4.8kWp east facing roof mounted array (10° pitch) combined with a 1.2kWp vertical south facing array was modelled in PVSyst. A Mastervolt SunMaster QS 6400 5.2kW inverter was selected with an array of 30 Kyocera KC200GHT-2 Polycrystalline 200Wp PV modules. 24 panels were modelled as being roof mounted with 6 panels modelled as a south facing façade array. When modelled in PVSyst, 3985 kWh/year is calculated for available energy at the inverter output. This value is 7% lower than the SAP-calculated value, which is consistent with the tendency of SAP to overestimate the performance of PV for non-optimal orientations. The SAP rating obtained by replacing the SAP-predicted PV output with the PVSyst value is A93, i.e. a reduction of one unit.

SIGMA House + SDHW modelled in SAP

The installation of SDHW at the Sigma Home utilises 4 SCHOTT EPC 16 Evacuated Tube SDHW collectors and 2 Schuco 200 L dual coil unvented cylinders. The solar collectors are on a pitched roof facing South, with a slope of 35°. In the absence of manufacturer data the thermal loss coefficient of each 200 L tank was assumed to be at the higher end of "B" band in EN15322, i.e. 1.94 kWh per 24h (3.88 kWh/day for two tanks). Hot water usage per day was set to be 126.7 L, as defined in SAP Table 1.

SIGMA Home + SAP v9.82 calculation to determine contribution to domestic hot water

With SCHOTT EPC 16 Technical Information:

$Q_s = S * Z_{panel} * A_{ap} * \eta_0 * UF * f(a_1/\eta_0) * f(V_{eff}/V_d)$

$Q_s = 1042 * 1 * 3.23 * 0.773 * 0.646 * 0.823 * 1$

$Q_s = 1381$ kWh/year

This increased the SAP Rating from C73 to C78.

SIGMA House SDHW modelled in TRNSYS

The installation described above was modelled in TRNSYS. The calculated solar input is 1839 kWh (33% above the SAP value) and the water heater output is 1831 kWh (9% under the SAP value), with increased tank losses (620 kWh vs 340 kWh, i.e. an increase of 82%). The SAP rating obtained by using the TRNSYS-calculated water heater output in SAP is unchanged at C78 (the actual value increases from 77.74 to 78.45, both of which are rounded to 78).

SIGMA House + SDHW + PV modelled in SAP

With the previously described PV and SDHW modelled together in SAP, the calculated SAP Rating is A99.

If the results of PVSyst and TRNSYS are used in the main SAP procedure, the calculated rating is unchanged at A99 (it actually decreases from 99.39 to 98.64, both rounded to 99). The PV output is corrected downwards and the solar thermal input is corrected upwards, resulting in a small downwards correction overall.

CONCLUSIONS

The comparisons between SAP 2005 v9.82 and PVSyst simulations show a very good agreement for the base case photovoltaic system (30° slope, facing south, standard system components, and Sheffield weather data). The difference in energy output at the inverter is 2%. SAP only uses the rated peak power of the PV array in the calculation and assumes a central weather location. Detailed PVSyst simulations show that using different system components (e.g. thin film versus mono-crystalline cells) can lead to differences of +/-10% in output. This leads to a difference of +/-1 in the SAP rating if the PV output calculated by PVSyst is used in the SAP assessment. Simulations were performed using weather data recorded at one station representative of Northern England and Southern Scotland, and one station representative of Southern England. This leads to differences within [-11% / +19%] PV output and [-1 / +2] in equivalent SAP rating. By combining the impact of different weather locations and different system components, PVSyst shows differences within [-18% / +33%] in PV output and [-1 / +3] in equivalent SAP rating. Results for different slopes and azimuth angles also show that SAP seems to systematically overestimate the performance of PV systems for unfavourable orientations (e.g. vertical West or East facing), and slightly underestimate the performance for more favourable orientations (e.g. 60° facing South). This is probably explained by the fact that SAP does not take into account the impact of incidence angle.

SAP assessment of solar thermal domestic hot water systems (SDHW) was compared to detailed TRNSYS simulations. TRNSYS results for a standard system using SAP default parameters for collector efficiency show a solar input which is 23% higher than SAP results, but the tank losses are also larger which results in the water heater output to be only 7% lower. The SAP default parameters for collector efficiency are significantly lower than typical values published by the IEA. Results show that using SAP default parameters instead of IEA default parameters leads to under-predicting the savings at the water heater output by 35%. If certified parameters are available, they can be used in SAP, and comparisons using the same efficiency parameters in TRNSYS and SAP shows that the differences increase for higher performance collectors. Using IEA typical Evacuated Tube data, TRNSYS predicts a higher solar input (+47%), a lower water heater output (-23%) and an improved SAP rating (C75 vs. C74).

As for the PV, SAP assumes one location representative of the whole UK. Using weather data for Southern England, leads to differences of up to 60% in solar input and up to 31% in water heater output. The SAP rating obtained by utilising these values in the SAP procedure leads to an improved rating: (C75 vs. C74). The results also show that SAP seems to underestimate the performance of SDHW systems when the slope is increased, as it ignores the impact of a better match between supply and demand when available radiation is increased in winter and reduced in summer. SAP seems to use a conservative estimate for the pumping energy, which is set to 75 kWh for all systems. TRNSYS simulations using a typical pump rated power (25 W) show that the energy use is between 50% and 75% of the SAP value.

DISCUSSION AND FUTURE WORK

This study has shown a good agreement between SAP results and detailed simulations for PV and a reasonable agreement for SDHW systems, when the most typical system configurations are used. It was highlighted that SAP is restrictive as specific values for PV panels, inverters and SDHW systems cannot be measured.

As SAP relies upon a series of simple equations, there is less scope for errors to occur in calculations. This contrasts with detailed analysis tools such as TRNSYS and, to a lesser extent, PVSyst. These systems offer a greater degree of detail to be modelled, but the learning curve required to use these detailed systems is as high as the opportunity to make calculation errors.

The centralised weather location of Sheffield utilised by SAP allows for homes throughout the UK to be compared directly. However, this has the effect of overestimating PV and SDHW output in northerly areas of the UK whist underestimating output in southerly areas of the UK. Different system configurations and weather data locations were simulated and showed significant differences in performance, up to 35%. This seems to be even more the case for SDHW systems with high efficiency collectors, which could be explained by the fact that SAP does not explicitly take into account the utilisation of the solar resource. SAP ratings are typically affected by differences smaller than 1, but in some cases differences of 3 have been noted. As SAP is sometimes used to rank energy saving measures, these differences can be significant.

Future work will investigate the performance of SDHW systems in more detail: impact of design parameters (e.g. setpoint temperature, tank volume and losses), and draw-off profile. The systematic

differences noted in this study (ignoring the incidence angle impact for PV and the supply-demand match and solar radiation utilisation for SDHW) will also be investigated in detail with the view to suggest improvements to the SAP methodology. Future work is also needed to assess the impact of shading. It is well known that shading can have a devastating effect on PV performance, and it is unclear how the basic categories in SAP can address this.

It is expected that many of the differences identified in this study can be addressed if SAP moved towards regional monthly degree day calculations as defined in BREDEM-8 (Anderson et al, 2001). An additional improvement on accuracy could be obtained if the optimum angle for delivering maximum output from the solar collector, on a UK regional basis, was provided and utilised in SAP.

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REFERENCES

Anderson, B. R., Chapman P. F., Cutland N. G., Dickson C. M., Doran S. M., Henderson G., Henderson J. H., Iles P. J., Kosmina L., and Shorrock L. D. 2001. BREDEM-8 Model Description, BRE

Anderson, B. R., Chapman P. F., Cutland N. G., Dickson C. Henderson G., Henderson J. H., Iles P. J., Kosmina L., and Shorrock L. D. 2001. BREDEM-12 Model Description, BRE

Bahij A. S., James P. A. B. 2006. Urban Energy Generation: the added value of photovoltaics in social housing. Renewable and Sustainable Energy Reviews 11 (2007), pp2121 - 2136

British Standards. 2007. BS EN 15332:2007. BSi.

BRE, 2008. SAP 2005. The Government's Standard Assessment Procedure for Energy Rating of Dwellings. 2005 Edition, revision 2, BRE.

Contract Journal, 2006. Renewable initiatives hit by software snags. http://tinyurl.com/cd4byt, accessed on 2009-02-24

Cooper, G.A., 2008. SAP 2005 and Low Energy Dwellings. Oxford Brookes University, UK.

Dalgarno, S. 2009. Personal Communication. Stewart Milne Group.

DCLG, 2007. Building Regulations Energy efficiency requirements for new dwellings – A forward look at what standards may be in 2010 and 2013. Department for Communities and Local Government, London, UK

Energy Saving Trust, 2009 [online]. Generate your own Electricity; Solar Electricity. Available: http://tinyurl.com/cj6fqo accessed 2009-02-24

IEA-PVPS, 2007. Trends in Photovoltaic Applications – Survey report of selected IEA countries between 1992 and 2007. Report IEA-PVPS T1-17:2008. International Energy Agency, Photovoltaic Power Systems Programme. St. Ursen, Switzerland

IEA-SHC, 2004. Recommendation: Converting solar thermal collector area into installed capacity (m^2 to kW_{th}). International Energy Agency, Solar Heating and Cooling Programme. Available from www.iea-shc.org accessed 2009-02-24

Lyle, A. 2009. Personal Communication. Renewable Devices Energy Solutions Ltd.

Meteotest 2009. Meteonorm - Global Meteorological Database. V.6.1.

PVSyst. 2009. Study of Photovoltaic Systems – V.4.33. University of Geneva, Switzerland.

Perers, B., Bales, C. 2002. A Solar Collector Model for TRNSYS Simulation and System Testing. IEA – Solar Heating and Cooling Programme.

Ren, M J., Cotton, M., Brown, K., Palmer, G. 2007. Meeting the current and future challenges for sustainable building designs – Case studies. Proc. 10th International Building Performance Simulation Conference and Exhibition, pp 1831-1838.

SAVE N° XVII/4.1031/Z/99-261, 2001. BELAS - Energy Labelling of Existing Buildings.

Syed, A M., Fung, A. S., Ugursal, V. I. 2007. Analysis of the Potential of Using Photovoltaic and Wind Turbine Energy Systems in the Canadian Residential Sector. Proc. 10th International Building Performance Simulation Conference and Exhibition, pp 665-672.

TESS, 2007. TRNSYS Type 604, multi-node pipe model. Personal communication. Thermal Energy Systems Specialists, Madison, WI.

TRNSYS. 2009. TRNSYS 16. Thermal Energy System Specialists, LLC. Madison, Wisconsin.

Weiss, W., I. Bergmann and G. Faninger, 2008. Solar Heat Worldwide – Market and Contributions to the Energy Supply 2006 – Edition 2008. IEA, Solar Heating and Cooling Programme. AAE Intec, Gleisdorf, Austria.

Wittchen K. B., 2003. Building Integrated Photovoltaics in a Thermal Building Simulation Tool, Proc. 8th International Building Performance Simulation Conference and Exhibition, pp 1417-1422.