Consultation Paper: CONSP:08

Amendments to SAP's hot water methodology

Issue 1.0

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1. INTRODUCTION

This paper proposes improvements to the calculation used to estimate the energy required for water heating in SAP. The existing procedure is outlined, its limitations discussed and proposals for improvements are made.

1.1 The existing calculation of hot water energy requirement

SAP 2012's calculation of water heating energy requirement begins with an estimate of the volume of hot water required, $V_{d,average}$ (litres/day). This is a function of the number of occupants[1], N, only.

$$V_{d,average} = (25 * N) + 36$$

Since occupancy is typically between 2 and 3 in the majority of cases this commonly yields hot water volumes of between 80 and 110 litres per day. This equation is based on monitored hot water consumption data from 112 homes collected in 2006/7[2]. This is considered to be a reasonably robust source of data and representative of UK homes.

The study also found that hot water use varies by month of the year, being around 20% higher in winter than in summer, so a monthly volume correction factor is applied to the annual average to calculate the daily hot water demand for each month, $V_{d,m}$ (litres/day).

Table 1 - Volume correction factor for each month of the year

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1.10	1.06	1.02	0.98	0.94	0.90	0.90	0.94	0.98	1.02	1.06	1.10

The monthly temperature rise, ΔT_m (°C), imparted by the water heater to raise the temperature during water heating was also measured in the study. Based on this, SAP

[1] This is not actual occupancy, but a standardised occupancy, since SAP is an asset rating tool.

[2] Measurement of Domestic Hot Water Consumption in Dwellings. Prepared by Chris Martin, Energy Monitoring Company for the Energy Saving Trust. March 2008.

2012 assumes the required volume of water is heated from the cold water supply temperature by an amount which varies with the month of the year as shown in table 2.

Table 2 - Monthly temperature rise required to provide hot water, ΔT_m (°C)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
41.2	41.4	40.1	37.6	36.4	33.9	30.4	33.4	33.5	36.3	39.4	39.9

Combining the volume of hot water required with the temperature rise, the energy required to heat the water can readily be calculated using the heat capacity of water (4.18 kJ/K/litre) and the number of days in each month, n_m.

Energy content of hot water = $4.18 * V_{d,m} * n_m * \Delta T_m / 3600$ (kWh/month)
(Dividing by 3600 converts from kJ to kWh)

Added to this is the energy required to overcome various system losses:

- Distribution pipework losses
- Primary pipework losses (between boiler and cylinder)
- Standing losses from hot water storage vessels
- Combination boiler losses (e.g. start-up losses)

Subtracted from this is any hot water generated by a solar water heating (SWH) system, waste water heat recovery (WWHR) system, or a flue gas heat recovery (FGHR) system.

The sum of all of the above gives the total energy requirement for water heating. This is divided by the efficiency of the water heating device to calculate the amount of fuel required, allowing fuel costs and CO_2 emissions associated with water heating to be estimated.

1.1.1 Interactions with other methodology within SAP

The volume of hot water used has a significant impact on energy yields from SWH and WWHR. In particular their performance is significantly affected by the type of shower used in the home. Therefore adjustments relating to shower type are made in their particular calculation methodologies:

- The SWH calculation gives reduced savings where an electric shower is used.
- The WWHR calculation takes account of the fact that WWHR is only used with higher flow rate mains pressure mixer showers.

1.2 Shortcomings of the existing methodology

In small, well insulated homes hot water consumption can be a larger load than space heating. In that context it could be argued that SAP's water heating calculation is too simple compared to the space heating calculation.

More specifically, the present hot water calculation:

- Doesn't take account of shower type despite this being one of the most important fixed and assessable features of a dwelling affecting hot water consumption.
- Contains inconsistencies in approach for SWH and WWHR, which effectively use a different hot water demand from the rest of the calculation in an attempt to correct for shower type not being taken into consideration in the main hot water demand calculation.
- Doesn't take proper account of the electricity used by electric showers.

1.3 Improvements required

Undoubtedly the biggest improvement we could make to SAP's hot water calculation would be to take account of the flow rate of any showers installed in the dwelling. Showers are generally a fixed and identifiable feature of a dwelling, so it should be practical for SAP assessors to obtain this information. Furthermore shower type already forms part of the data collected during a Green Deal Occupancy Assessment giving further confidence that this is workable.

Shower type is a highly relevant factor for the following reasons:

- Hot water use for baths and showers makes up around 2/3rds of all hot water use in the UK, with the majority of that used for showers.
- There is a significant difference between the flow rates of different types of shower. In particular, showers provided from an unvented (mains-pressure) source, such as a combi boiler, have flow rates found to be nearly twice as high as those from vented (header tank) systems[3]. Assuming shower durations are not significantly different this will lead to nearly twice as much hot water being used per shower.
- The savings from some technologies depend strongly on the type of shower present (especially SWH and WWHR), so it is difficult to represent them accurately without using a calculation which takes explicit account of shower type.
- If an electric shower is present, this will result in a different fuel being used for a more significant proportion of water heating than is assumed in the calculation. In this case, much less hot water may be drawn from the 'main' water heating system. At present the electrical consumption of this shower type is not dealt with in SAP.

Calculating the amount of hot water used for showers explicitly will allow us to simplify and improve the calculations for SWH and WWHR.

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[3] *Water and Energy Efficient Showers: Project Report*, Richard Critchley, United Utilities and Dr David Phipps, Liverpool John Moores University. 2007.Since this source is used multiple times in this report for brevity it will henceforth denoted *UU/LJMU*.

2. PROPOSED AMENDMENTS FOR SAP 2016

2.1 Hot water volume calculation

We propose that a daily hot water requirement in litres/day is calculated separately for three categories of use:

- Hot water required for showers, $V_{d,shower}$
- Hot water required for baths, $V_{d,bath}$
- Hot water required for other uses, $V_{d,other}$

These would then be combined to give a total daily hot water demand for each month.

$V_{d,average}$ (litres/day) = $V_{d,shower} + V_{d,bath} + V_{d,other}$

The calculation of each of the three elements is described below.

2.1.1 Volume of hot water required for showers

It is proposed that the amount of hot water used for showering is calculated for each shower present in the home *individually* then summed, rather than by working out an average flow rate and doing a single calculation. This makes things simpler in the updated WWHR calculation, described later. This is achieved by running through the following steps for each shower present in the home:

A. Determine the number of showers per day
B. Determine the shower flow rate
C. Determine the total water use per shower
D. Determine the hot water use per shower
E. Determine the hot water use per day

A. Number of showers per day

The number of showers per day is in practice highly occupant dependant, but for SAP some kind of average or typical behaviour must be assumed, for a given number of (assumed) occupants. A relationship based on occupancy has been developed. This was derived by converting data in the form of showers per person per day based on UU/LJMU data into a SAP "AN+B" style of equation by scaling the A and B coefficients to predict an identical number of showers for an average number of occupants (2.36). Data was only available to do this for homes which also had a bath (since all the homes in the sample had a bath), but it was possible to rescale the coefficients again to cover cases where no bath is present based on the equations for shower total water use in DCLG's water calculator. These assume showers are used 0.78 times as often where a bath is also present.

Showers per day	= 0.45 N + 0.65 (if bath also present)[4]
Or	= 0.58 N + 0.83 (if no bath is present)

Where multiple showers are present, it is assumed they are all used equally[5], so the number of shower uses per day for all showers is divided by the number of showers present in the home to get the use for a particular shower unit.

B. Shower flow rate

The most important physical factors affecting flow rate are the hot water pressure and the presence of any flow restrictors, since these determine the maximum flow rate that can be achieved. The former depends most strongly on the plumbing characteristics of the hot water system. However occupant behaviour is also a factor so we have based the assumed flow rates in table 3 on averages associated with each plumbing arrangement taken from field data[6,7], assuming no flow restrictors are fitted. A correction can then be made where limiters are fitted.

[4] This is the same as the equation already used in the Occupancy Assessment methodology

[5] It is likely in practice that certain showers will be used preferentially to others, but it is difficult to envisage a method for assigning weights reflecting preference.

[6] UU/LJMU

[7] *Potential Water Savings through the use of HL2024 Shower Flow Regulators*, Dr D.B. Sims-Williams, Dr H.A. Bulkeley, Dr P.C. Matthews, Mr G.D. Powells, Durham University. 2008.

Table 3 - Proposed shower flow rates (l/min) by plumbing arrangement:

Vented hot water system	7
Vented hot water system + pump[8]	12
Unvented hot water system	11
Instantaneous electric shower (vented or unvented)	0[9]

If a permanent flow restrictor[10] is known to be fitted (i.e. one requiring the use of tools to remove), the restricted flow rate should be used in place of these figures, down to a lower limit of 6 l/min[11]. Part G of the building regulations requires that showers fitted to new homes have their flow rates restricted to no more than 8l/min, so the highest unrestricted flow rates in the table are only likely to be used for existing dwellings.

In practice SAP assessors may not find these categories intuitive to use, so a series of questions and logic is provided in Appendix A to assist in choosing the correct category.

C. Total water use per shower

Showers are assumed to last 6 minutes[12]. Therefore:

Total water use per shower (l) = 6 * flow rate

D. Proportion of shower water that is hot

Showers are assumed to be delivered at 41°C[13], made up of a mixture of cold and hot water. The proportions of hot and cold water required depend on the temperature of the hot and cold components relative to the desired shower temperature, denoted T_{hot}, T_{cold}

[8] Showers with built-in pumps, commonly referred to as *power showers*, would be included in this category, as well as showers fed by a whole-house pump used to increase the hot water pressure generally.

[9] Instantaneous electric showers have only a cold water feed, so use no hot water.

[10] There is a case for allowing for water-saving shower-heads, since these have the potential to provide better comfort for a given flow rate by aerating the water, compared to flow restrictors.

[11] If a shower with an unacceptably low flow rate shower is provided there is a high risk it will be replaced by householder with a higher flow rate unit. This is discussed further in section 3.1.

[12] It is possible that shower duration might increase in showers with low flow rates, but we found no evidence to support this.

[13] *UU/LJMU*

and T_{shower} respectively (all in °C). The temperature of cold water varies by month of the year. This is taken from the existing table G2 in SAP 2012:

Table 4 - Cold water feed temperature, T_{cold}, in °C (SAP table G2)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
11.1	10.8	11.8	14.7	16.1	18.2	21.3	19.2	18.8	16.3	13.3	11.8

This data was based on EST field trials in 2008, which also revealed that the average temperature of hot water, T_{hot}, provided was 52°C, with no significant monthly variation.

The proportion of hot is calculated based on the requirement to provide shower temperature water, T_{shower}, at 41°C:

Proportion hot = (T_{shower} - $T_{cold,m}$) / (T_{hot} - $T_{cold,m}$)

This gives the following proportions of hot water for each month:

Table 5 - Proportion of hot water required for showers in each month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.731	0.733	0.726	0.705	0.694	0.675	0.642	0.665	0.669	0.692	0.716	0.726

E. Daily hot water use for shower

This is the product of the volume of water per shower, the proportion of that which is hot and the number of showers per day taken using shower outlet X:

$V_{d,showerX,m}$ (litres/day) = Total water per shower * Proportion hot * Showers per day

Finally, the monthly figure obtained for each shower type is multiplied by an additional monthly behavioural variation factor, as described in section 2.2 (table 8).

Having calculated this for each shower present in the dwelling the figures are summed to give the total daily showering hot water volume for each month.

$V_{d,shower,m}$ (litres/day) = $V_{d,shower1}$ + $V_{d,shower2}$ + etc…

2.1.2 Hot water required for baths

The amount of hot water used in baths is equal to the product of the amount of hot water used per bath and the number of baths per day. It is not necessary to consider each bath present individually if more than one is present since they are assumed to be more or less identical[14]. If *any* bath is present the following steps are used.

Total volume of water used per bath

The average volume of water used per bath is assumed to be 73l[15] (i.e. the mixture of hot and cold), taken from UU/LJMU (referring to a Water Research Council study in 2005).

Proportion of hot water

Assuming:

- a required bath temperature of 42°C
- average hot water temperature of 52°C
- a monthly cold water feed temperature taken from SAP table G2 (i.e. table 4 in this report)

The proportion of hot water required in each month is calculated in table 6.

Table 6 - Proportion of hot water required for baths in each month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.756	0.757	0.751	0.732	0.721	0.704	0.674	0.695	0.699	0.720	0.742	0.751

Multiplying by the assumed bath volume gives the volume of hot water per bath in each month of the year (in litres), shown in table 7.

Table 7 - Volume of hot water required for baths in each month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

[14] Shorter baths are occasionally installed in small homes. However, these are likely to result in deeper baths being taken, so the effect on hot water use may well be small. In any case, no evidence was available to consider these separately.

[15] Other estimates found ranged from 69 to 85 litres

55.2	55.3	54.8	53.4	52.7	51.4	49.2	50.7	51.0	52.6	54.1	54.8

Number of baths per day

Field data[16] shows that baths are used significantly more frequently in homes where no shower is present. The following relationships were derived using the form of the existing SAP hot water volume equations as a starting point, rescaling to match the data.

Baths per day = 0.13 N + 0.19 (if at least one shower is present in the dwelling)
Or = 0.35 N + 0.50 (if there is no shower in the dwelling)

In the rare case of a dwelling with no bath and no shower, for the purposes of calculation it should be assumed that a bath is present, but no shower.

Daily hot water consumption for baths

The hot water requirement for baths in month m is given by:

$V_{d,baths,m}$ (litres/day) = Hot water use per bath * Baths per day

These values are then multiplied by an additional monthly variation factor, described in section 2.2.

2.1.3 Volume of hot water required for other uses

The remaining hot water use is calculated as a simple function of the number of occupants, N. This was derived by taking the remainder of the SAP 2012 hot water volume after the proportions attributed to baths and showers have been removed. Averaging over all shower/bath combinations for the UK (weighted using ownership data from Market Transformation Programme), it was estimated that 61% of hot water is used for baths and showers, leaving a remainder of 39% for other uses. Therefore the coefficients in the SAP 2012 hot water equation were multiplied by 0.39, giving:

$V_{d,other}$ (litres/day) = 9.8 N + 14

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[16] Also from *UU/LJMU*

This average figure for the year is then multiplied by monthly variation factors, as described in section 2.2.

2.2 Monthly adjustments

Data from the EST study used to derive the water heating equations for SAP 2012 showed that hot water requirement (volume drawn) varied by month, being around 20% higher in January than in July, on average. There appear to be two aspects to this:

- the monthly variation in cold water feed temperature (affecting the proportion of hot needed in showers and baths, or to fill sinks)
- occupant behaviour (people might take more baths in winter or cooler showers in summer, for example).

In SAP 2012 both aspects were taken into account using a single factor for each month applied to all hot water use to give the 20% variation. In the proposed method for SAP 2016, the first aspect is dealt with explicitly in the proposed shower and bath calculations, but not for 'other' hot water use. The latter aspect is not yet dealt with for any use, so a correction is required.

In the shower and bath calculations the summer/winter swing due to varying cold water feed temperature, already accounted for, is around 14% (i.e. ±7%) for shower hot water requirement and 12% for baths (based on tables 5 and 6), suggesting the remaining 6-8% is still to be accounted for. Therefore it is proposed that the hot water requirement calculated for bath and shower energy is corrected by applying a 7% summer/winter swing (i.e. ±3.5%). The full 20% swings should still be applied to 'other' hot water use, using the existing table 1c values in SAP 2012. Overall this will give swings in total hot water consumption of around 20%, retaining consistency with the field data.

The new monthly volume factors needed to introduce the correct swings are shown in tables 8 and 9.

Table 8 - Monthly variation factors to apply to baths and shower ($MF_{b\&s}$)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1.035	1.021	1.007	0.993	0.979	0.965	0.965	0.979	0.993	1.007	1.021	1.035

Table 9 - Monthly variation factors to apply to other hot water uses (MF_{other})

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1.10	1.06	1.02	0.98	0.94	0.90	0.90	0.94	0.98	1.02	1.06	1.10

Once the monthly adjustments have been applied to the shower, bath and other monthly hot water volumes, they can be used to calculate total monthly hot water requirements.

2.3 Instantaneous electric showers – electricity use

Electric showers which heat water instantaneously from cold to a comfortable shower temperature are common in the UK (found in around 45% of homes according to MTP figures). These do not use any hot water; they only have a cold water feed. However, the significant amount of electricity they use does need to be accounted for in SAP.

$E_{shower,m}$ (kWh/month) = Showers per day * electricity use per shower * n_m
(where n_m is the number of days in the month)

Showers per day is based on the same figure as for other shower types. See section 2.1.1.

The amount of electricity used per shower is calculated from the power rating of the electric shower assuming a shower duration of 6 minutes (i.e. 0.1 hours):

Energy use per electric shower (kWh) = Power rating (kW) * 0.1 (hours)

The actual rated power should be used where known (e.g. in the case of new homes), otherwise a default value of **9.3 kW** is assumed. This is the average figure for electric showers in UK homes, based on MTP data.

If there is more than 1 electric shower present, the electricity consumption of each unit should be calculated individually, assuming the number of showers required is divided equally between all showers present in the dwelling, and then summed to give the total.

No monthly adjustment is required for electric showers to take account of varying cold water feed temperature since their power output is constant. However, the behavioural related variation (e.g. longer showers in winter) factor is still needed, as for other shower types. This is taken from table 8.

2.3.1 Heat gains from electric shower use

Account also needs to be taken of the internal gains due to use of electric showers. It is proposed these are treated in the same way as the gains from water heated by other means; therefore 25% of the energy input is assumed to be released within the dwelling (with the remainder assumed to be drained away). The simplest way to enact this is to adjust the water heating gains formula used to calculate worksheet item $(65)_m$ of SAP 2012, as follows:

Heat gains from water heating, kWh/month =
$0.25 * [0.85 * (45)_m + (61)_m + E_{shower,m}] + 0.8 * [(46)_m + (57)_m + (59)_m])$

Where
$(45)_m$ is the energy content of heated water from the main system
$(61)_m$ is the combi loss
$(46)_m$ is the distribution loss for water supplied by the main system
$(57)_m$ is the storage vessel loss
$(59)_m$ is the primary circuit loss

2.4 Associated adjustments to SWH, and WWHR procedures

If the hot water consumption equations are adjusted to take into account shower type there will no longer be any need to make adjustments for shower type in a piecemeal fashion in the SWH and WWHR methodologies. This will result in a consistent approach to hot water requirement across SAP. To align with the proposed new hot water calculations described above the following changes will be needed.

2.4.1 Solar water heating

The hot water volume adjustment factor (step H7a in the SAP 2012 SWH calculation) and table H3 should be removed. This will no longer be relevant. No other changes are required.

2.4.2 Instantaneous waste water heat recovery

More significant changes will be required to the WWHR calculation. The current procedure described in SAP 2012, Appendix G section 2.2 uses a two stage process. First a bottom-up approach is used, assuming showers with higher than average flow rates are present, since WWHR is used with unvented (mains pressure) hot water systems. Then a top-down approach is used, based on the usual (lower) SAP hot water requirement. The average saving (i.e. heat recovered) from the two methods is used as the final figure. This compromise was reached in order to avoid the potential for the savings from WWHR to exceed the stated hot water requirement earlier in the calculation.

Now that we are proposing to directly include shower type as an input to the hot water requirement calculation there is no longer any need to use a compromise approach and the top-down approach can be dropped completely. Also, since the approach to hot water demand now calculates the water use for showers and baths separately, the procedure can be further simplified (e.g. the potentially confusing parameter SB_{mix} is no longer needed).

The proposed approach is therefore conceptually very simple:

A. Calculate the amount of heat that is potentially recoverable (the energy content of the water passing through the WWHR unit(s) during shower operation).
B. Multiply this by the efficiency with which the unit(s) recover heat

B is dealt with simply using two product specific parameters taken from the Product Characteristics Database (PCDb):

- η, the unit's steady-state heat recovery efficiency, obtained from a lab test.

- UF, a utilisation factor taking account of unrecoverable heat at the beginning and end of shower events. This is a calculated value based on the heat and water capacity of the WWHR unit.

There has been discussion with industry and in a recent BRE report[17] of possible changes to the method used to calculate UF. Its calculation is not directly a part of the SAP methodology, so changes to it are not within the scope of the SAP consultation exercise. Nevertheless, as a relevant matter, UF issues are discussed in Appendix B of this document.

Calculation of the amount of heat potentially recoverable

Where there is only one shower and one WWHR system present the recoverable energy would be equal to the total volume of warm shower water used during a shower multiplied by the heat capacity of water and the temperature difference between the water at the drain and the incoming cold water. The calculation is complicated by the need to cater for multiple showers and multiple WWHR units. Thus the problem is largely to determine what proportion of shower use occurs in showers draining into each WWHR unit (which may have different heat recovery characteristics). The following data is therefore required:

- Total number of showers (collected as part of the main hot water inputs)
- The number and flow rate of showers draining into WWHR unit 1, 2, etc.

For each shower present, its connection to a particular WWHR unit must be established. The following steps and *example* (in blue italics) show the process required.

1. List any WWHR units present and retrieve their PCDb characteristics (η, UF).

e.g. *WWHR1: η=0.5, UF=0.95*

WWHR2: η=0.4, UF=0.9

2. Associate showers present to WWHR units.

e.g. Shower1: Type=unvented, feeding WWHR1

Shower2: Type=unvented with 8l/min flow restrictor, feeding WWHR1

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[17] *Waste Water Heat Recovery - A Review of Calculation Algorithms*, Sean Doran, BRE. April 2015.

Shower3: Type=unvented with 6l/min flow restrictor, feeding WWHR2

Shower4: Type=electric, not currently applicable for WWHR

3. Retrieve *warm* water[18] consumption for each shower from the main hot water calculation (section 2.1.1 step C) and multiply by the number of uses per day, assuming use is divided equally between all showers present.

e.g. *1.8 uses per day with 4 showers gives 0.45 uses per day each…*

*Shower1: 11 l/min * 6 min * 0.45 showers/day = 32.4 l/day (to WWHR1)*

*Shower2: 8 * 6 * 0.45 = 21.6 l/day (to WWHR1)*

*Shower3: 6 * 6 * 0.45 = 16.2 l/day (to WWHR2)*

*Shower4: 0 * 6 * 0.45 = 0 l/day (not to WWHR)*

4. Sum water flow to each WWHR, $V_{ww,x}$ (l/day).

e.g. *WWHR1:* $V_{ww,1} = 32.4 + 21.6 = 54.0$ *l/day*

WWHR2: $V_{ww,2} = 16.2$ *l/day*

5. Multiply daily volumes by the number of days in the month, n_m, and the behaviour related month factor, $MF_{b\&s}$ (from table 8), to get monthly warm water volumes for each WWHR unit, $V_{ww,x,m}$ (l/month).

$$V_{ww,1,m} = V_{ww,1} * n_m * MF_{b\&s}$$

e.g. $V_{ww,1,Jan} = 54 * 31 * 1.035 = 1733$ *l/month* *(repeat for each month)*

$V_{ww,2,Jan} = 16.2 * 31 * 1.035 = 520$ *l/month* *(repeat for each month)*

6. For each month establish the energy content of warm water reaching each WWHR unit, $Q_{ww,x,m}$ (kWh/month), with respect to the monthly cold water feed temperature, $T_{cold,m}$ (°C, from table 4). As in the SAP 2012 calculation, a temperature drop of 6°C between shower head and the WWHR unit heat exchanger is assumed, so the energy content is based on a drain temperature of 41-6 = 35°C.

$$Q_{ww,x,m} \text{ (kWh/month)} = V_{ww,x,m} * (35 - T_{cold,m}) * 4.18 / 3{,}600$$

e.g. $Q_{ww,1,Jan}$: *1733 * (35 - 11.1) * 4.18 / 3,600 = 48.1 kWh/month*

$Q_{ww,2,Jan}$: *520 * (35 - 11.1) * 4.18 / 3,600 = 14.4 kWh/month*

(repeat for each month)

7. The monthly energy saving for each WWHR unit, $S_{x,m}$ (kWh/day), is then calculated by applying the factors η and UF (from their PCDB records).

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[18] This is total water at shower temperature (i.e. mix if hot and cold) so differs from the hot water volume.

$S_{x,m} = Q_{ww,x,m} * \eta * UF$

e.g. $S_{1,Jan} = 48.1 * 0.5 * 0.95 = 23.0$ *kWh/month*

$S_{1,Jan} = 14.4 * 0.45 * 0.9 = 5.8$ *kWh/month*

(repeat for each month)

8. The savings for each WWHR unit are summed to give the total WWHR saving, S_m (kWh/month).

2.4.3 Storage waste water heat recovery

Storage WWHR (SWWHR) systems are able to make use of heat recovered from baths as well as showers because the recovered heat does not need to be used immediately. SAP allows for one SWWHR system per dwelling and not a combination of storage and non-storage types.

The proposed procedure for calculating savings is similar to that for non-storage systems: the amount of potentially recoverable heat is calculated then this is multiplied by the efficiency and utilisation factor.

The amount of heat potentially recoverable is calculated as follows:

1. Determine which baths and showers feed into the SWWHR system.
2. Calculate the volume of warm water[19] available from each source for each month of the year.
3. Calculate the energy content of the water from each source with respect to cold feed temperature
    a. for showers this is the same as step 6 for non-storage WWHR
    b. for baths this is $V_{ww,bath,m} * (42-T_{cold,m}) * 4.18 / 3,600$
4. Sum for the sources to get the total energy potentially recoverable each month, $Q_{SWWHR,m}$ (kWh/month).

The monthly energy saving for SWWHR, $S_{SWWHR,m}$ (kWh/day), is then calculated by applying the factors η and UF (from their PCDB records):

$S_{SWWHR,m} = Q_{SWWHR,m} * \eta * UF$

[19] I.e. at shower or bath temperature - not the hot water temperature.

3. IMPACT OF PROPOSED CHANGES

The main impacts of the changes proposed are as follows:

- The volume of hot water required will vary considerably with shower type.
- Consequently the predicted energy consumption associated with water heating will vary far more from home to home. Two homes which currently have the same DER or SAP rating, but have different shower types, would receive different ratings in future.
- The savings from SWH and WWHR will be either higher or lower than at present due to their performances being highly dependent on the hot water demand. Savings from WWHR will usually be higher (since they are used with higher than average flow rate showers)[20]. Saving from SWH will be higher than at present if showers with high flow rates are used and lower if lower flow rate showers are used.

The proposed changes will more accurately reflect the performance of the dwelling than the present calculation, which should help encourage better (e.g. lower carbon) decisions to be made by those building or retrofitting homes.

3.1 Consideration of any possible unintended consequences

Generally we would expect the consequences of the changes proposed to improve accuracy by better reflecting the energy consequences of hot water related building characteristics.

A possible unintended consequence is that builders of new homes may be tempted to install showers with flow rates that are unacceptably low to occupants in order to achieve Part L compliance (DER) at minimal cost. If the householder then replaces the shower with a device with a higher flow rate, or removes any flow restrictors installed, any energy and CO2 benefits from the original low flow rate will prove short lived. By including a lower

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[20] But a home with a high flow rate shower *and* WWHR will not necessarily have lower energy consumption than one with a lower flow rate shower *without* WWHR.

limit of 6 l/min for deliberately flow-restricted showers (below which no further energy or CO2 benefit will be recognised) it is hoped this scenario will be avoided.

4. SUMMARY

The method to determine hot water consumption in SAP 2012 does not take account of an important factor affecting hot water use – shower type. This paper therefore proposes a new procedure which calculates the amount of hot water used by showers according to their flow rates, as well as for baths and ‘other’ uses of hot water. This makes for a more transparent calculation as well as allowing a detailed consideration of the effect of shower type.

Moving to this method also tidies up some inconsistencies in SAP 2012, where piecemeal corrections have been applied in calculating the savings from SWH and WWHR. In the case of WWHR this actually makes the calculation simpler.

Overall, these changes should improve the accuracy of SAP’s predictions of hot water energy consumption significantly. The only potential negative consequence identified is that this change could encourage house-builders to install showers in new homes which have flow rates that are unacceptably low to occupants, who might then replace them with types with higher flow rates; hence an attempt has been made to avoid this.

However, the benefits to calculation accuracy make a strong case for taking the approach described in SAP 2016.

Appendix A – Determination of plumbing arrangement

The choice of plumbing arrangement type used to work out shower flow rates described in section 2.1.1 may not be intuitive to many SAP assessors, at least at first, so the following logic is suggested as a way to assist them in getting the correct choice.

a) **Choose basic shower type**: Instantaneous electric shower (cold feed only), Mixer shower

If electric shower, select 'Instantaneous electric shower (vented or unvented)'. No further information needed.

If mixer shower, continue…

b) **Choose hot water source**: Combi, Hot water cylinder

If combi, select 'Unvented hot water system'. No further information needed.

If cylinder, continue…

c) **Choose cylinder type**: Fed by header tank (Yes or No?)

If No (mains pressure), select 'Unvented hot water system'.

If Yes, continue…

d) **Choose pump type**: No pump, Pump for shower, Pump for all hot water.

If no pump, select 'Vented hot water system'.

Otherwise select 'Vented hot water system + pump'.

This could either be included in the SAP specification (requiring the above inputs and the use of this process), or dealt with as a SAP assessor training issue and left to accreditation bodies.

Appendix B: WWHR utilisation factor

Purpose of UF

The UF takes account of shut-down and start-up losses. It is expressed as a factor between 0 and 1 (but in practice between 0.86 and 1[21] for units currently listed in the PCDb – averaging 0.93, a 7% loss). This is applied (by multiplication) to the calculated figure for the energy recovered.

Criticism of current calculation

Starting conditions

The assumption that the WWHR unit returns to cold water feed temperature at the beginning of a shower has been challenged. The current assumption is that any room temperature water initially contained within the unit and in feed pipework will be purged with cold water during the shower warm-up period, before the user has entered the shower. It is therefore considered as a loss. The validity of this assumption requires consideration of system arrangement.

For a ‘System B’ arrangement, as described in SAP 2012, whereby the output of the heat exchanger is fed to the shower only, in practice the flow of cold water through the unit will not start until the hot water temperature reaching the shower unit has reached shower temperature (e.g. 41°C) due to the action of the mixer valve; hence no purge will take place. With a ‘System A’ or ‘System C’ arrangement, where cold water flow through the WWHR unit will begin as soon as the shower is turned on, the room temperature water will indeed be purged, but will end up either in a hot water cylinder, or at the combi boiler. In both cases this will be of some use. In the case of a hot water cylinder it is there in place of cold water; it is therefore all useful. In the case of a combi, it will allow the combi’s heat exchanger to warm more quickly than if cold water had been circulating, so it is of *some* use in shortening the combi heat-up time (it will not be 100% utilised however due to the imperfect heat exchange with the combi). Therefore, the existing assumption in all cases looks too pessimistic. It would be too optimistic to assume it is 100% useful in the case of

[21] It is only possible to achieve 1 with storage WWHR systems.

combis, so there is an argument for using a different procedure depending on whether the system arrangement.

Gains from pipework losses

The heat lost from the unit itself and its in-feed pipework during post-shower cool down is lost within the heated space of the dwelling. This will be of some use during the heating season by contributing to internal gains. At present this benefit is ignored on the basis that it is insignificant. However, this is technically incorrect and it could potentially be included either by adjusting the calculation of the UF used to generate the PCDb figure (assuming some loss is in fact useful, increasing utilisation), or by explicitly including it as a source of gains within SAP. In practice this is likely to make a very small difference to the answer.