Recoup Energy and Showersave

Waste Water Heat Recovery Systems Standard Assessment Procedure Evidence Evaluation

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Contents

Executive summary

Tight energy and carbon performance improvement targets will support the transition to a net zero carbon UK economy, ending the UK contributions to global warming by 2050. Critical to the achievement of this target, is the improved energy and carbon performance of new homes in the UK. With proposed changes in the Standard Assessment Procedure (SAP 10.1) and the UK Government's Future Homes Standard consultation (Part L and F consultation), this is a great opportunity to reflect and re-examine the methods utilised to assess the energy performance of new homes. The current research, undertaken by Currie & Brown UK Ltd on behalf of Recoup Energy Solutions Ltd and Building Products Distributors Ltd. focuses on three main areas of interest.

- The SAP assessment and prediction of new homes occupancy levels, following historic SAP changes and literature review data
- The review of methods used within SAP to estimate Domestic Hot Water (DHW) demand
- The impact of involved parameters, and assumptions on showering routines, affecting potential energy saving calculations from Wastewater Heat Recovery systems

The main challenges within the DHW SAP method include the ability of the procedure to assess the number of occupants in the new home, their typical behaviour in terms of DHW energy use and calculating the amount of hot water and energy used. Currently the common link between most of these aspects is the total floor area (TFA) of the property. Through assessment of empirical data, a link is made between the TFA and the number of occupants within SAP.

Utilising data from the 2011 Census and literature review evidence, the research identifies potential risks within the current occupancy estimation methodology. Based on research findings, a relationship between the number of bedrooms within a new building and the number of occupants could support a better representation of the potential number of occupants within the property. Other changes within the SAP10/10.1 methodology investigated, highlighted that the proposed showering duration of 6 minutes, as seen within the proposed SAP10/10.1 methodology, could be an underestimate. A shower duration of 8 minutes may be more appropriate to use.

Differences between the currently used SAP2012 DHW daily consumption predictions, and the new SAP10.1 method were checked. Outputs indicated a 30% increase in DHW demand predicted in SAP10.1 when compared to the current SAP version (2012). Flowrates and showering frequency assumed within SAP10.1 appear to be in alignment with research findings.

Current complexities within the SAP DHW methodology are that historically inherited elements and empirical reduction factors introduce a level of detail that is likely to enhance errors within the approach.

It is strongly recommended that all information used within SAP in terms of DHW are published, with all substantiating evidence detailed. It is also advised that special consideration is given to the effect of changes on WWHRS, a passive technology that is key to delivering DHW energy demand reductions and is in full alignment with the Future Homes Standard and Climate Change Act commitments.

While the accurate representation of an occupant behaviour within new homes in terms of DHW is not sought, current assumptions within SAP10.1 lead to a potential expected energy saving (less energy used for example per shower) but may hinder the take up of WWHRS and similar technologies with a guaranteed benefit to DHW energy savings.

1. Introduction

New homes are expected to have a low energy demand. This is usually achieved through the reduction of the energy required for heating following mainly a fabric first approach (airtight, highly insulated thermal envelope).

Services such as energy efficient combi boilers and heat pumps ensure that the low heating energy requirements are covered with the minimum amount of grid energy supply possible. Other solutions such as Mechanical Ventilation Heat Recovery systems are also utilised commonly utilised to recover heat from ventilation systems and have not only been an important element in the government's approach to energy efficient homes, but also mandatory to use if optional highly-energy efficiency standards such as the PassivHaus were to be achieved.

As energy demand for heating continues to decrease in new homes, the necessity for addressing reductions in energy demand for domestic hot generation becomes significant. Wastewater Heat Recovery Systems (WWHRS) offer the unique opportunity to recover heat captured within disposed warm water in drains. A simple passive design system expected to last for as long as the duration of the installed pipework is critical to supporting the delivery of the government carbon reduction/climate protection targets.

The government's current target for the housing industry is to deliver 300,000 new homes per year by 2025 and to continue delivering similar numbers moving forward. There is a unique opportunity to deliver these new housing units with high quality and sustainability credentials. The aspiration is visible when looking into the recent consultation document 'The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings' which suggests that in 2025 a new house that meets the Future Homes Standard (semi-detached) will produce on average 75-80% less carbon emissions than one built to current standards.

Achieving these high targets depends both on the ability of the government to introduce correct policies and milestones, as well as provide the industry with the right tool to evaluate their current delivery performance. Currently the Standard Assessment Procedure methodology – SAP2012- is used to confirm compliance with the Building Regulations. While SAP is recognised as a compliance and not a 'design' tool, in the sense that the performance calculations conducted within the software are not expected to reflect the exact reality of the performance of the property, due to its very nature, it can 'promote' or 'hinder' the take up of specific technological solutions depending on how well they perform when applied within the software application.

While substantial efforts have been made to identify the best method to identify how much energy may be required for heating, the method for the calculation of DHW is still lacking. SAP utilises historic data and a function linking predicted hot water use to the floor area of the property (from which indirectly the occupancy levels are calculated) for the main DHW calculations. Whilst the impact of WWHRS on energy recovered was estimated using an almost separate to the main DHW calculation process approach.

The impact of SAP is two-fold: it can affect the take up of a technology and it can introduce solutions that might not be able to deliver the benefits in real life (and vice versa). It is therefore important that the SAP evaluation methodology for technologies such as the WWHRS is carefully examined. With the new SAP 10/10.1 and later remaining under consultation, this research report opens the dialogue for revaluation and examination of the SAP methodology examining the DHW consumption of new homes.

The current research looks into the main parameters utilised within SAP for the DHW predictions, the references utilised substantiating the different calculation processes in place, and literature review data, acting as the first of evidence necessitating the re-examination of the method used.

2. Methodology

The main focus of this research has been the evaluation of the Domestic Hot Water (DHW) calculations used within SAP both historically and as presented within the current proposed (under consultation) SAP 10/10.1 version.

In terms of the research process, SAP technical manuals of the following editions: SAP 2005, SAP 2009, Sap 2012 and SAP 10/10.1 were examined and reviewed. The main focus has been the calculation processes associated with the DHW demand predictions.

As well as the SAP Technical Manuals, historic technical papers, consultation papers on methodological changes and methodology statements as reported by BRE contributing to the development of the BREDEM methodology and SAP functions was collected and analysed.

Internal and external references identified through the various technical documents were explored and added to the literature review undertaken.

The literature review was expanded using search strings and relevant keywords focusing on domestic hot water, showering routines and domestic hot water break down consumption data for England and Wales, expanded where appropriate to include national and international evidence.

Research included information as extracted from the 'WWHRS: Summary and overview of conversations, November 2019' attached as an Appendix to this document, and supplied by Recoup WWHRS. Information presented with the client's note was cross-referenced and re-examined by the researchers for accuracy and removal of potential bias.

SAP outputs were calculated by simulating the described processes within excel and by cross-referencing outputs with samples run through the SAP 9.92 (SAP2012) and the online SAP10/10.1 beta software of method.

Statistical data analysis was undertaken, as extracted from the Office of National Statistic and government departments (Census 2011, MHCLG construction rates and information on housing delivery characteristics – historic and current) supplementing existing datasets where required.

In addition, anonymised data on housing stock characteristics through the evaluation of national house-builder new home typologies was obtained by AES Sustainability Consultants, reviewed and utilised to support findings from publicly available information.

While this research was initiated through the identification of potential discrepancies in the evaluation of the WWHRS within SAP, no direct evaluation of WWHRS is included with the report. Provision of specific WWHRS information and analysis could mis-direct the focus of this exercise which is to establish potential SAP DHW calculation 'weaknesses' that can hinder the delivery of the energy and sustainability national and international targets.

Critical to the evaluation of the SAP DHW methodology was deemed to be the assumptions around the assumed occupancy of the new homes and the relationship of the number of occupants to the total floor are of the properties. Early in the process and prior to the research being initiated it was agreed that the potential link between occupancy, total floor and the number of potential bedrooms within the property would be examined and be potentially linked. This was due to the frequent presentation of occupancy data in association with the number of the bedrooms of a property.

A qualitative approach to data interrogation was selected for the research. While data analysed is considered as sufficient for the identification of trends and delivery of observations, analysis heavily relied on reported and published information already analysed by other researchers. Mean values and averages are commonly utilised throughout the report.

3. SAP Occupancy and Domestic Hot Water (DHW) calculation methods review

3.1 Levels of occupancy

3.1.1 SAP Calculation methods

SAP is used to predict the energy and carbon performance of new and existing residential properties following a standardised steady-state energy balance approach.

To date, the occupancy levels of a property evaluated in SAP is estimated utilising the total floor area (TFA) of the property under examination. Historically one change has occurred in the function utilised, shown in Table 1 below.

Table 1 - SAP Assumed Occupancy formulae

SAP Version	Occupancy Levels (Function)	Source
SAP 2005	N = 0.0365 TFA – 0.00004145*TFA^2, TFA <= 450m^2 N = 9 / (1 + 54.3 / TFA), TFA > 450m^2	[Ref8]
SAP 2009	N = 1+1.76*[1-exp (-0.000349*(TFA -13.9)^2)] + 0.0013*(TFA-13.9), TFA >= 13.9 m^2 N = 1, TFA<13.9 m^2	[Ref2]
SAP 2012	N = 1+1.76*[1-exp (-0.000349*(TFA -13.9)^2)] + 0.0013*(TFA-13.9), TFA >= 13.9 m^2 N = 1, TFA<13.9 m^2	Same 2009
SAP 10	N = 1+1.76*[1-exp (-0.000349*(TFA -13.9)^2)] + 0.0013*(TFA-13.9), TFA >= 13.9 m^2 N = 1, TFA<13.9 m^2	Same 2009
SAP 10.1	N = 1+1.76*[1-exp (-0.000349*(TFA -13.9)^2)] + 0.0013*(TFA-13.9), TFA >= 13.9 m^2 N = 1, TFA<13.9 m^2	Same 2009

The revision in the method occurred due to findings from the English House Condition surveys (2002-2005) [Ref.9].

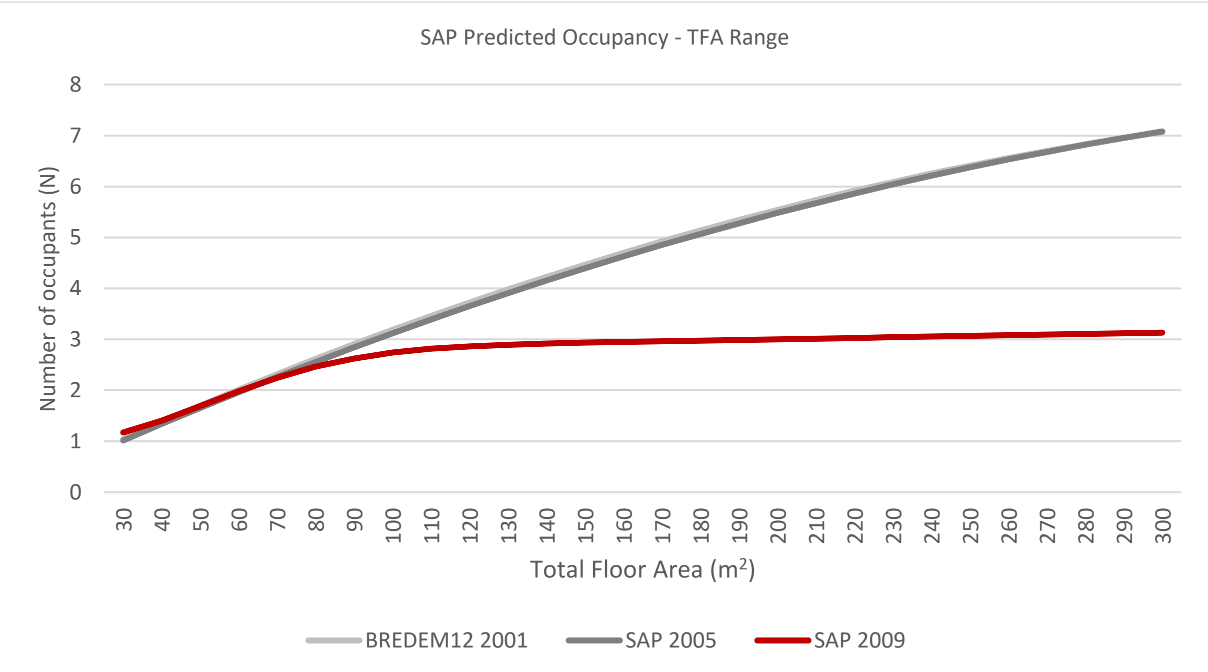


Figure 1 – SAP2005 V SAP2009 (2012/10/10.1) - Predicted levels of occupancy for a range of TFA

3.1.2 Data from literature review analysis

Since 2009 no further edits occurred within the SAP 'levels of occupancy' calculation method. While this in effect means that the method used today utilises reference data that is more than 15 years old, that does not necessarily mean that it does not remain relevant.

SAP predicted occupancy levels are of critical importance to the SAP Domestic Hot Water (DHW) calculations.

The following data was used in the examination of the SAP2009 predicted occupancy levels methodology:

- 2011 Census – Data sets providing actual information on national housing and its occupants. Outputs are used by policy makers to measure inadequate accommodation and offer details in terms of household occupancy structures (historic and current trends) [Ref3]

- Technical housing standards – nationally described space standards setting out minimum requirements for the Gross Internal (floor) Area of new dwellings for defined levels of occupancy and dimensions for key parts of the home, notably bedrooms, storage and floor to ceiling height. [Ref.4]

- Anonymised information on national new home archetypes used by main House Builders across the country (AES Sustainability Consultants data) [Ref.5]

- Live tables on house building: new build dwellings [Ref.6]

3.1.2.1 2011 Census Data

Information on the number of people per bedroom was extracted from 'QS413EW - Persons per bedroom – Households'.

- In ~ 22% of the cases more than 1 person per bedroom was identified.
- In ~ 50% of the case 0.5-1 person per bedroom was identified

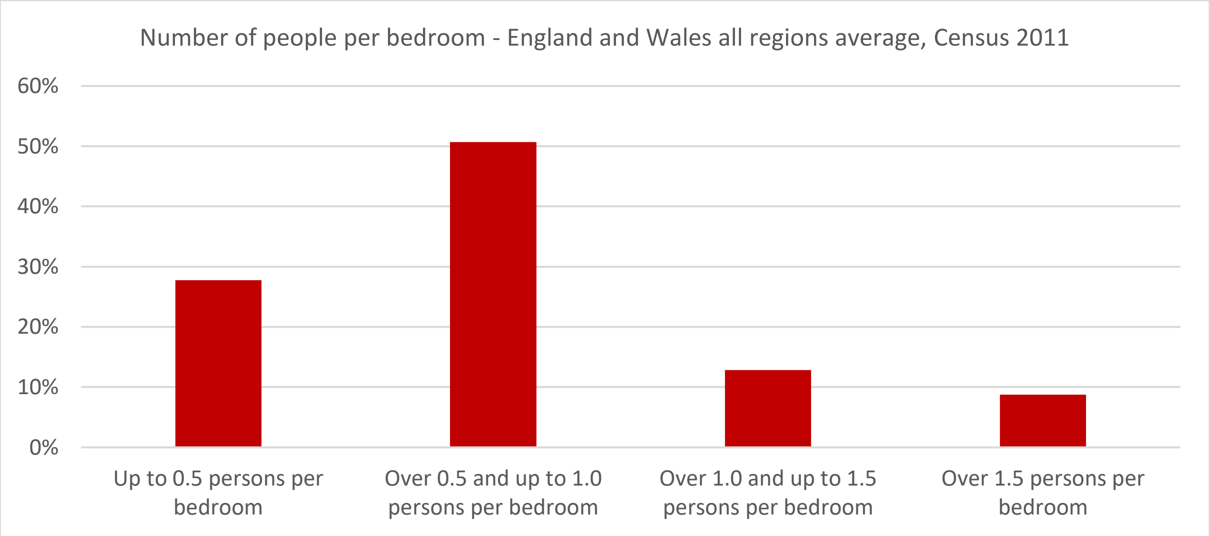


Figure 2 – Distribution of number of occupants per bedroom across all properties, Census 2011

Data includes all property types/sizes.

DC4405EW - Tenure by household size by number of bedrooms data was utilised to identify the relationship between the occupancy levels (persons per bedroom) and the number of bedrooms in the properties.

Results are provided within *Table 2*.

Table 2 – Number of occupants per bedroom, distributions based on property size, Census 2011 All tenures

Number of bedrooms	Average Nocc per bedroom – Al tenures
1 Bedroom	1.36
2 Bedrooms	1.0
3 Bedrooms	0.85
4 Bedrooms	0.76
5 Bedrooms and more	0.69

Data was also analysed in terms of tenure type, to investigate particular differentiation within different tenure types. More specifically the following categories were noted within the Census 2011 data

Table 3 - Tenure types within the Census 2011, All tenures categories

All categories: Tenure
▪ Owned or shared ownership: Total
▪ Owned: Owned outright
▪ Owned: Owned with a mortgage or loan or shared ownership
Social rented: Total
▪ Social rented: Rented from council (Local Authority)
▪ Social rented: Other social rented
Private rented or living rent free: Total
▪ Private rented: Private landlord or letting agency
▪ Private rented: Other private rented or living rent free

Two different approaches were followed. The re-estimation of occupancy levels based on All tenures minus 'Owned Outright' and the calculation of the occupancy levels of social rented. These two options were considered as appropriate based on the fact that SAP predicts the occupancy levels of new homes.

- Recent market trends indicate that most new homes are not 'owned outright'[1]
- In addition, social rented tenure type can be assumed as relatively vulnerable to running costs.

Results are presented within Table 4 and Table 5.

[1] https://www.gov.uk/government/statistics/help-to-buy-equity-loan-scheme-statistics-april-2013-to-30-june-2019-england

Table 4 - Number of occupants per bedroom, distributions based on property size, Census 2011 Excluding 'Owned Outright'

Number of bedrooms	Average Nocc per bedroom – All tenures excluding 'Owned Outright'
1 Bedroom	1.36
2 Bedrooms	1.0
3 Bedrooms	0.96
4 Bedrooms	0.86
5 Bedrooms and more	0.76

Table 5 - Number of occupants per bedroom, distributions based on property size, Census 2011 Social Rented total

Number of bedrooms	Average Nocc per bedroom – Social rented total
1 Bedroom	1.25
2 Bedrooms	1.05
3 Bedrooms	0.99
4 Bedrooms	0.96
5 Bedrooms and more	0.76

3.1.2.2 Technical housing standards – nationally described space standard (2015)

Information on minimum gross floor areas within the Technical housing standards – nationally described space standard (NDSS) [Ref.4] was utilised to assess the relationship between the number of bedrooms within a property and its floor area.

Table 6 - Average floor areas and association with the number of bedrooms allowed – NDSS Data

Number of bedrooms	TFA- Average (m^2)
1 Bedroom	49
2 Bedrooms	70
3 Bedrooms	92
4 Bedrooms	110

3.1.2.3 Anonymised data from actual national housing types from major housebuilders (PartL1A2013 compliant)

Anonymised data on main national housing types from major UK housebuilders (designs from the last 5 years) was provided by AES Sustainability Consultants.

Samples were taken from different housebuilders. The total number of samples reviewed and their sizes (B=bedroom) were as follows:

- Houses: ten (10) 2B, nineteen (19) 3B, twenty-one (21) 4B
- Flats: six (6) 1B, thirteen (13) 2B, six (6) 3B

Average TFA results obtained is shown below (Table 7)

Table 7 – Anonymised national design housing types V NDSS – average TFA (m^2)

Number of bedrooms	NDDS TFA- Average (m^2)	Houses Anon. Data TFA- Average (m^2)	Flats Anon. Data TFA- Average (m^2)
1 Bedroom	49	-	51
2 Bedrooms	70	66	72
3 Bedrooms	92	86	98
4 Bedrooms	110	117	-

The average TFA of the anonymised data did not deviate more than +/- 6.5% from the NDDS (*Figure 3, Figure 4*).

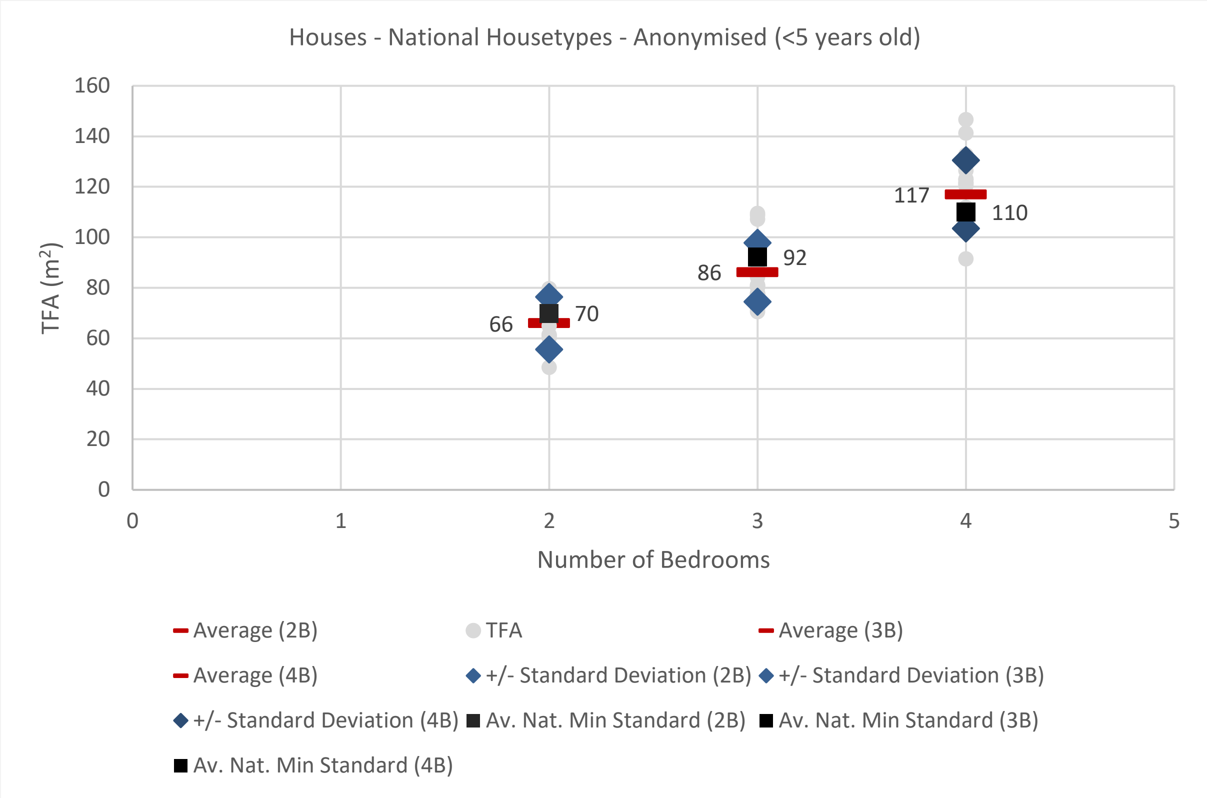


Figure 3 - National House types – Houses Part L1A 2013 – Analysis against NDSS

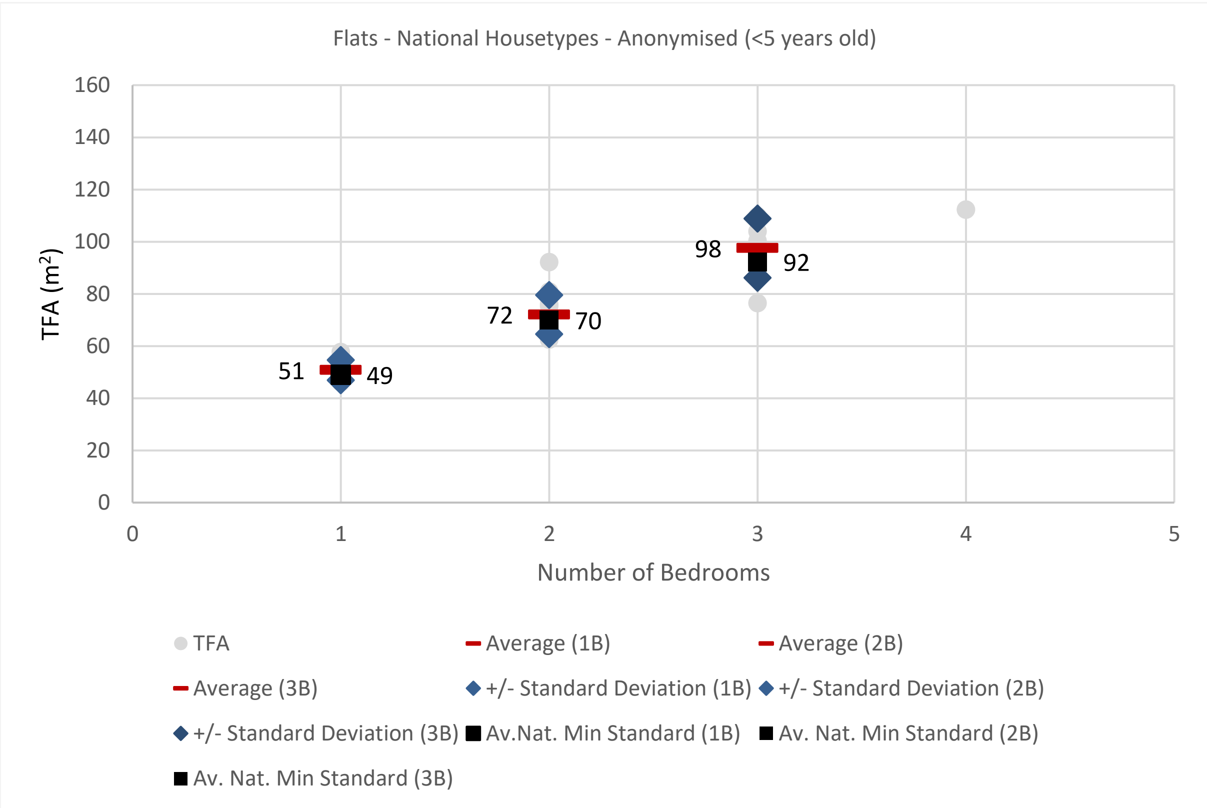


Figure 4 - National House types - Flats Part L1A 2013 – Analysis against NDSS

3.1.2.4 Prevailing housing typologies – New Housing trends

The government Live tables on house building [Ref.6] data was analysed and are shown in *Figure 5* and *Figure 6*.

Considering the last two years industry performance, ~160,000 new homes were completed on average per year (*Figure 7*).

This trend is expected to increase if the government targets are to be met of 300,000 new homes per year by the mid-2020s.

The following quantities were calculated based on a 160,000 dwelling per year delivery as per [Ref.6,7] data.

Table 8 – New homes statistics based on all tenures for different house types

	House type	(%) of 160.000	No. of units
Houses	1 bedroom	1%	1600
	2 bedrooms	14%	21600
	3 bedrooms	33%	52400
	4 or more bedrooms	30%	47600
Flats	1 bedroom	7%	11600
	2 bedrooms	15%	23600
	3 bedrooms	1%	1600
	4 or more bedrooms	0%	0

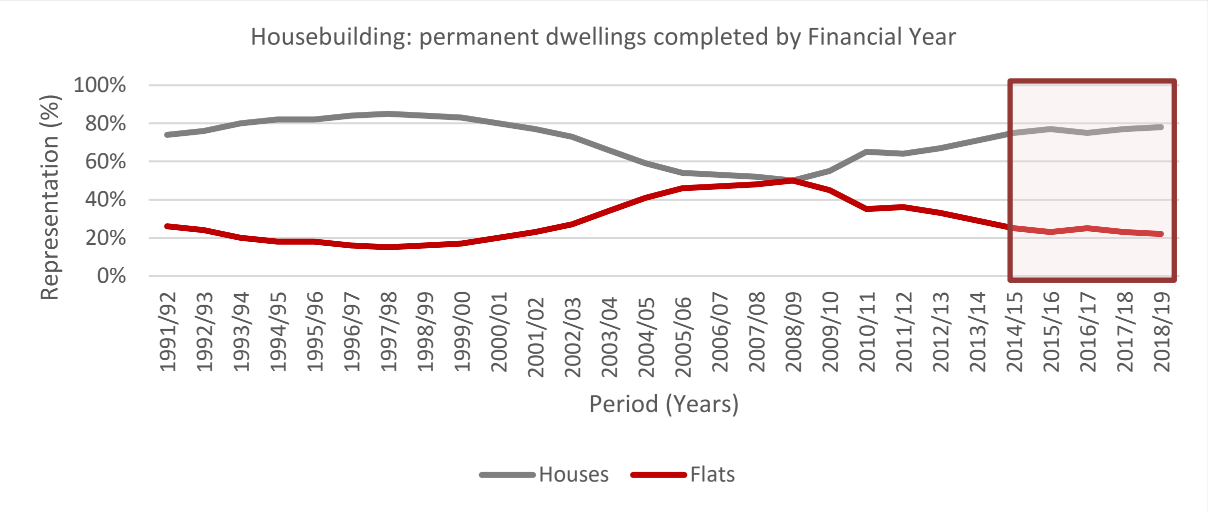


Figure 5[2] – 1991-2019 House Building trends – Houses v Flats national completions by financial year

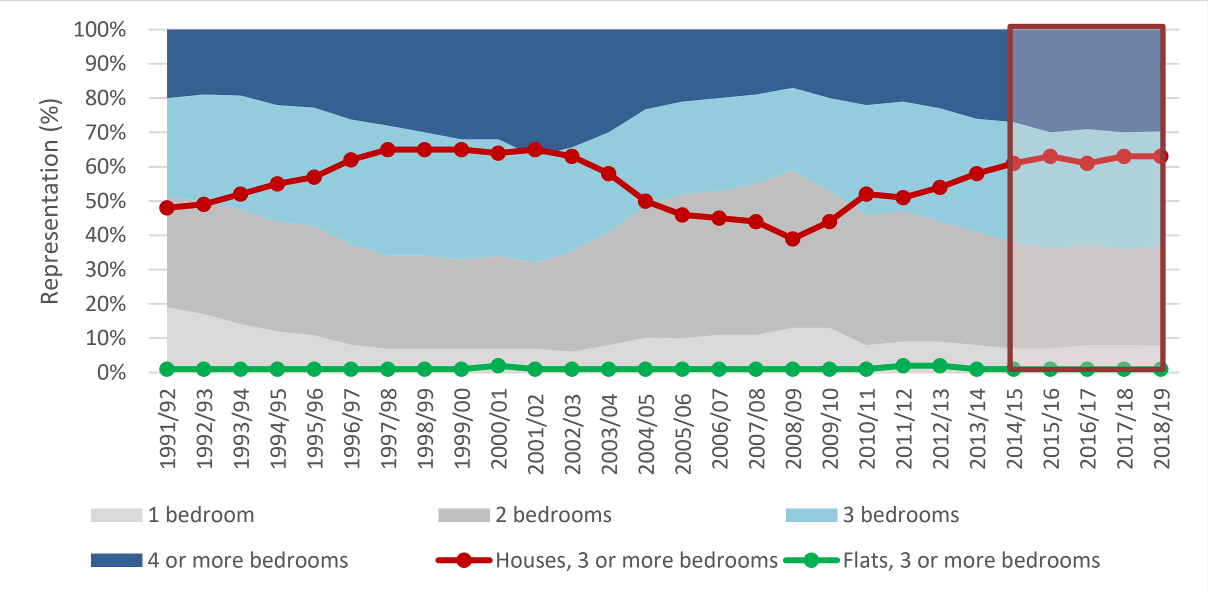


Figure 6 – 1991-2019 Housebuilding Trends – Housing types, size distribution based on number of bedrooms

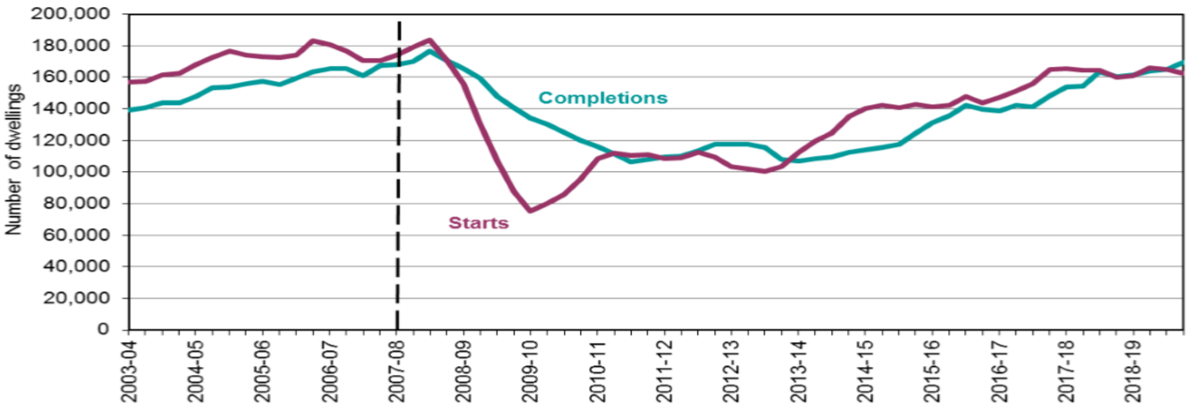


Figure 7 – 2003-2019 Trends in housing starts and completions, England [Ref.7]

[2] https://www.gov.uk/government/statistical-data-sets/live-tables-on-house-building - Figure 5 & 6

3.1.2.5 SAP methodology compared to literature review information

Average NDSS floor areas were used to predict occupancy levels for four typical new home typologies following two approaches:

- Occupancy levels based on TFA and SAP2012 predictions
- Occupancy levels based on number of bedrooms as calculated using Census 2011 data

Results are shown within the table below.

Table 9 – SAP2012/10.1 Predicted levels of Occupancy and Census 2011 Data

Number of bedrooms	TFA (m^2)	SAP2012	Census 2011 (All tenures)	Census 2011 Excluding Owned Outright	Census 2011 Social Rented total
1 Bedroom	49	1.66	1.36	1.36	1.25
2 Bedrooms	70	2.25	1.93	2.06	2.1
3 Bedrooms	92	2.65	2.55	2.88	2.96
4 Bedrooms	110	2.81	3.03	3.43	3.86

Discrepancies were identified between observed (Census 2011) and predicted (SAP2012) occupancy levels in all typologies.

What was noted as important was the potential underestimation of the occupancy levels for 3B when compared to Census 2011 'Excluding Owned Outright' and 'Social Rented total' and 4B-or-more when using any of the Census 2011 data sets.

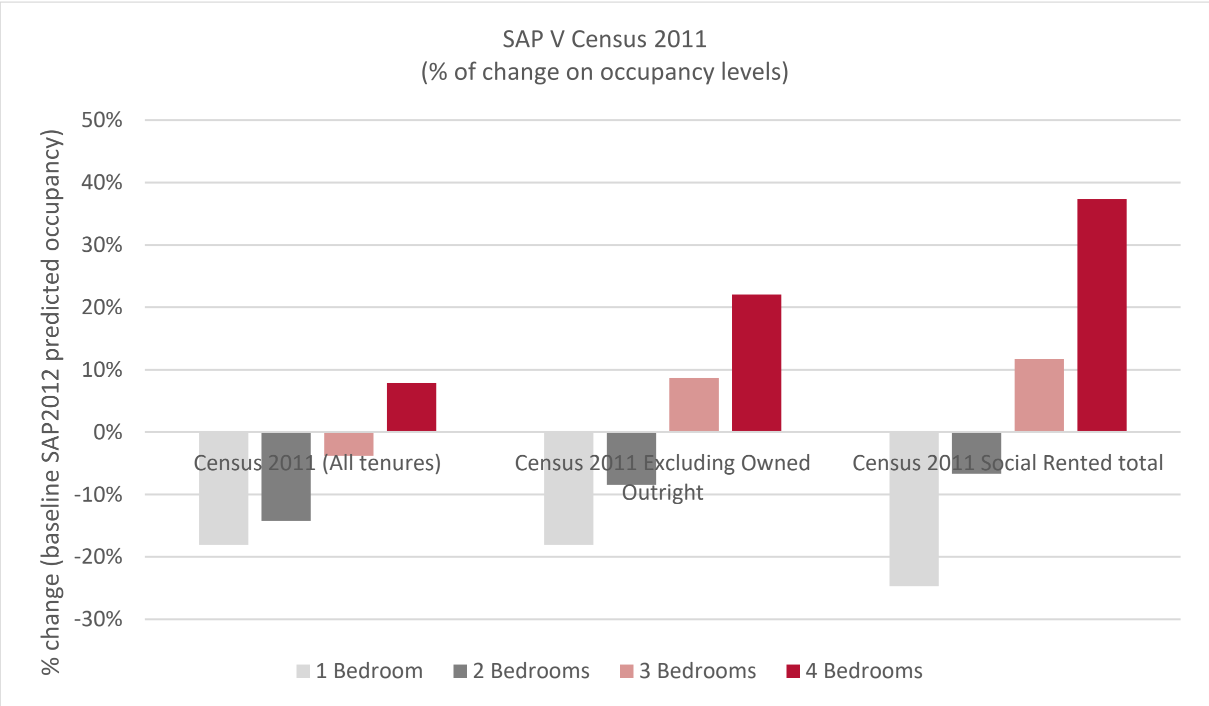


Figure 8 - Census 2011 % difference from SAP2012/10.1 Levels of occupancy

The potential over or underestimation of the DHW volume and energy demand will have a varying impact depending on the housing typologies expected to be delivered (*Table 8*).

It needs to be noted that with ~66% of new homes being a 3 or 4 bedroom property, the impact of inaccuracies in DHW energy demand predictions within these categories can be significant.

At the same time, properties purposed for social rent of that size can lead to increased running costs to a sensitive vulnerable group.

While this was expected based on the fact that SAP is not designed to accurately predict actual in-use performance, but rather set a baseline for buildings comparison, it was not clear why the predicted SAP occupancy levels are associated with the total floor area of a property rather than the number of bedrooms which could be a better indicator.

Table 10 - Energy content of DHW as predicted by SAP2012 methods for different occupancy levels

Number of bedrooms	TFA (m^2)	SAP2012 (kWh p year)	Census 2011 (All tenures)	Census 2011 Excluding Owned Outright	Census 2011 Social Rented total
1 Bedroom	49	1159.2	-112.8	-112.8	-153.6
2 Bedrooms	70	1377.6	-118.8	-69.6	-55.2
3 Bedrooms	92	1528.8	-38.4	85.2	115.2
4 Bedrooms	110	1590	80.4	230.4	390

Table 11 - Energy content of DHW as predicted by SAP10.1 method for different occupancy levels

Number of bedrooms	TFA (m^2)	SAP10.1 (kWh p year)	Census 2011 (All tenures)	Census 2011 Excluding Owned Outright	Census 2011 Social Rented total
1 Bedroom	49	1500	-145.2	-145.2	-198
2 Bedrooms	70	1783.2	-152.4	-90	-70.8
3 Bedrooms	92	1980	-49.2	110.4	148.8
4 Bedrooms	110	2058	104.4	297.6	506.4

A summary of findings includes:

- Analysis of NDSS data and anonymised national housing typologies information indicated a good alignment between NDSS TFA to number of bedrooms relationship. That relationship was used to analyse the predicted levels of occupancy between SAP and Census 2011 data.
- Discrepancies were identified between SAP expected occupancy level predictions and results as obtained from the Census 2011. Potential sensitivities were identified in the DHW calculation based on occupancy predictions for 3B and 4B homes.
- A question is raised as to whether or not the SAP method should be adapted to utilise the number of bedrooms as a potential indicator for the calculations of the occupancy levels rather than TFA. It could be more appropriate as number of occupants are more likely to be dictated by the number of bedrooms. Ranges for floor areas could also be introduced to convert TFA to number of bedrooms requiring confirmation from the SAP Assessor.
- Another potential consideration included the variability in occupancy levels predicted between different tenure types. While the potential representation of the different tenure types in the future within the new housing targets is not clear, it needs to be noted that trends may vary by region or at different times. This raised an additional question as to whether or not it could be of benefit for SAP to be a comparative tool to disassociate energy consumption calculations from the DHW consumption calculations and to establish a fixed level of occupancy levels per property type.
- As it was demonstrated, adapting occupancy levels based on the TFA through the use of a universal mathematical function is deemed to introduce deviations from observed data which can be exaggerated due to its connection to a metric such as the TFA. This could lead to a potential knock-on effect on the design of new homes' TFA as the energy utilised for the generation of DHW becomes a significant percentage of the total regulated energy used, moving forward to a carbon free housing stock.
- The SAP potential inaccuracies in terms of DHW demand, when associated with the new housing delivery predictions is magnified.
- It needs to be noted that a potential underestimation of the DHW use can negatively impact energy saving technologies such as the WWHRS.

3.2 Domestic Hot Water Demand

3.2.1 SAP Hot Water Demand Predictions

Since SAP 2005, the DHW demand is calculated based on the number of predicted occupants. As shown within *Figure 1* currently the predicted occupancy levels in SAP2009 and later are saturating to around 3 people per home in properties of more than >100m^2.

We reviewed current, proposed and historic DHW calculation methods used within the different versions of SAP. The following observations were noted [Ref.8]:

Table 12 - SAP Hot Water Demand

SAP Version	Hot Water Demand (Function) (l/day)	Source
SAP 2005	38 + 25*N, N= Assumed level of occupancy	[Ref8]
SAP 2009	36 + 25*N, N= Assumed level of occupancy, Vd, average (monthly factors)	[Ref9]
SAP 2012	36 + 25*N, N= Assumed level of occupancy, Vd, average (monthly factors)	[Ref9]
SAP 10	Vd,average = Vd,shower,ave + Vd,bath,ave + Vd,other,ave	[Ref10,11]
SAP 10.1	Vd,average = Vd,shower,ave + Vd,bath,ave + Vd,other,ave	Same SAP10

- SAP 2009: The B DHW coefficient (Ax Numb Occ + B) was reduced from 38 (SAP 2005) to 36. Monthly factors were employed to allocate DHW per month
- SAP 2012: Same methodology as in SAP 2009, only change was a minor edit within the function utilised to calculate the energy content of DHW
- SAP 10/10.1: a different methodology for the calculation of DHW consumption is proposed. DHW use is broken down into showering, bathing and other. Within the calculation method the number of showering outlets and baths define the pattern of use. Shower flowrates and duration of showers define the volume of water used. Monthly factors of DHW use are applied as in current SAP2012 version.

In order to investigate the impact of these changes to predicted amounts of DHW, each SAP version data was analysed for properties of a TFA of 30-200m2 and are plotted in *Figure 9*.

<u>Information in support of *Figure 8* explanation</u>

- Results are based on occupancy levels as predicted by the different SAP versions. For SAP 2009 and later a 5% reduction is used within the DHW consumption calculations to reflect a modern house with a total water consumption of <125 l per person per day

- SAP10/10.1 consumption data was based on a shower flowrate of 8l/min and a shower duration of 6min as per the consultation papers [Ref.13, 14]. In properties of 40-50m2 one shower outlet was assumed, in properties of 50-60m2 one shower outlet was assumed over a bathtub, in properties from 70-200m2, 2 shower outlets were assumed and a bathtub. Appendix J methodology was followed in MS excel

- For SAP 10/10.1 calculations the Annual average DHW demand was calculated and divided by 365 days within the year for the daily average to be produced.

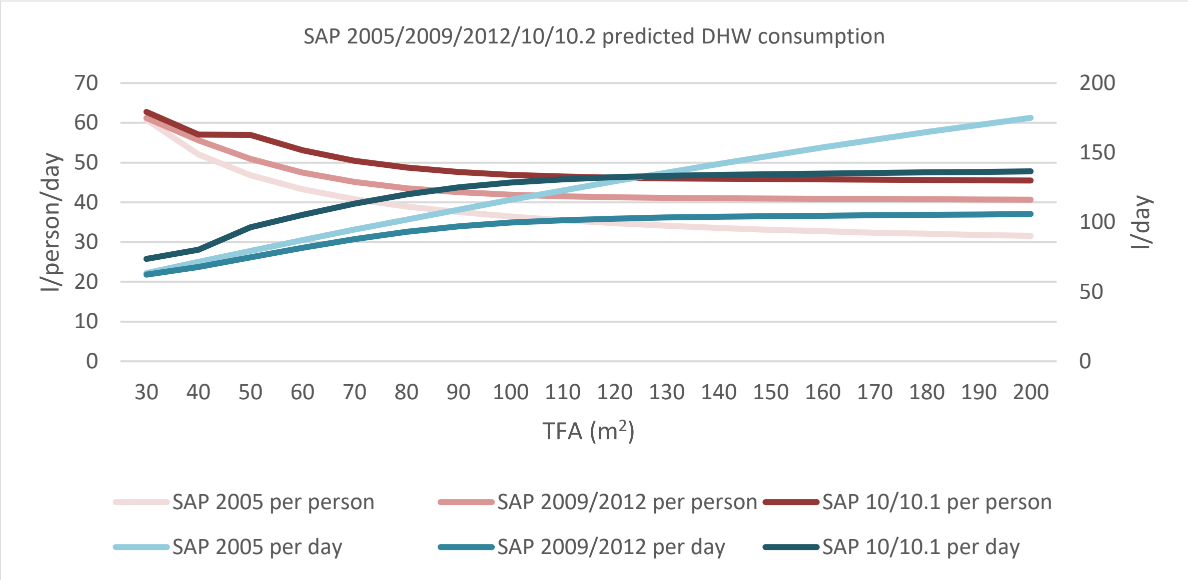


Figure 9 – SAP2005 to SAP10.1 DHW consumption predictions, Houses 30-200m^2 TFA

As observed, the proposed SAP10.1 version produced a notable difference, with a predicted increase of ~30% of DHW per day in properties larger than 60m^2 (when the presence of a bath and extra showers are assumed) when compared to the previous methodology used in SAP2012.

An analysis of the SAP10.1 methodology in terms of DHW volume allocation indicated that this is: 48% Showers, 22% Baths and 30% other.

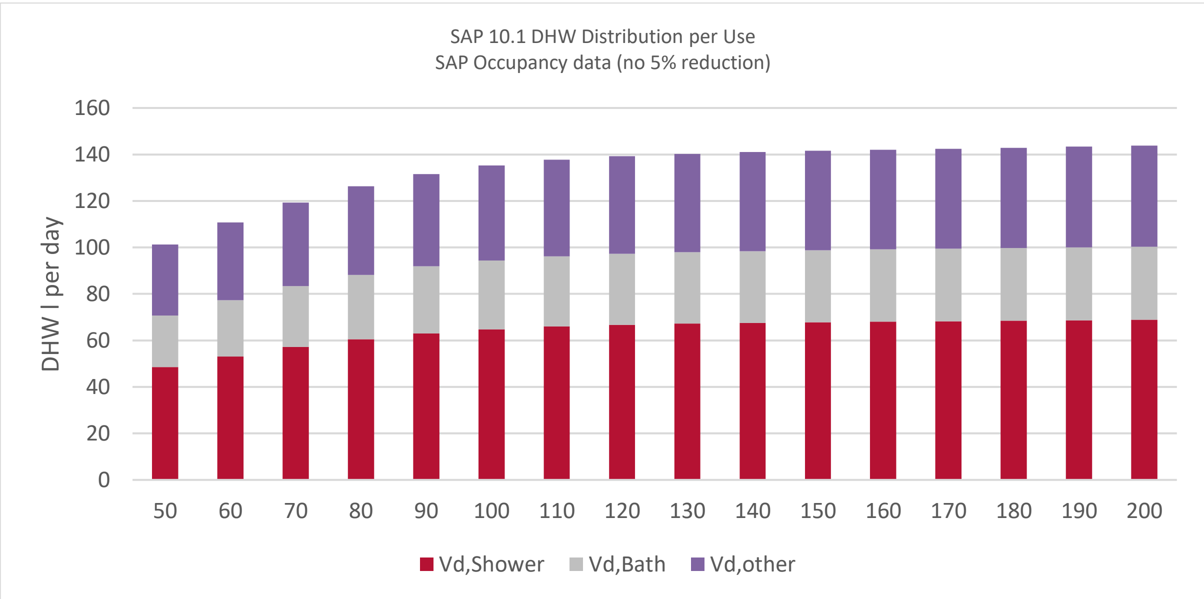


Figure 10 - DHW l per day distribution per use, range of TFA (m2)

3.2.1.1 SAP Predicted DHW consumption compared to literature review information

Research into the average hot water consumption per UK household has produced findings that all link back to the Energy Saving Trust data published in 2008 [Ref.14,15,16].

According to data analysed from 112 residential units, as presented within the STP09/DHW01 technical papers [Ref.9], the relationship produced between DHW and number of occupants - currently used in SAP2012 (36 + 25*N) – fairly represents the averages of records of that study.

Nevertheless, the paper concludes by suggesting that findings need to be considered with '*the work on the relationship between floor area and number of occupants and, doing this may suggest a need for some further adjustments'.*

The Consultation Paper: CONSP:08 – Amendments to SAP's hot water methodology – Issue 1.0, 2016 [Ref.11] is the basis of the new SAP10.1 DHW proposed methodology.

A summary of findings includes:

- Changes in the calculation method of DHW in SAP10/10.1 led to an overall increase of around 30% in terms of DHW demand per day (for currently suggested showering parameters)
- If the current methodology is accurate, the levels of occupancy may require adjustments to address concerns around actual DHW daily consumption and avoid unnecessary complexities that could introduce inaccuracies
- The 5% decrease in <125l of water consumption per person per day is applied to the calculation method even though the actual predicted DHW showering volumes are based on the flowrate and the durations of showering (already noted within the method). It is unclear why a further reduction is applied in the form of a % decrease.
- It needs to be noted that with a number of SAP parameters and the method approach a clear track record of changes along with reference information substantiating this approach will need to be provided by BRE
- It is recommended that additional research is undertaken to confirm the applicability of the new recommended approach based on DHW consumption of different property types
- An analysis of the SAP10.1 methodology in terms of DHW volume allocation pre type of use indicated that this is: 48% Showers, 22% Baths and 30% other. The 70% of DHW allocated to showering and bathing activities.

3.3 Showering duration and flowrates

3.3.1 SAP - Showering flowrates, duration and volume

SAP historic and current information has been analysed and is presented below [Ref.8]

SAP 2005:

- SAP 2005 adopted 75l as the volume of water in an average shower
- The shower flow rate was not defined within SAP
- Data used was extracted from the Liverpool John Moores University

SAP 2009:

- SAP 2009 used a shower flow rate of 9 l per min for the WWHRS efficiency measurements
- As suggested, if a duration of 6.5 minutes was to be considered then a total shower volume of 58.5 l would have been obtained but the SAP 2005 assumption of 75 l was maintained as this evidence came in later after release.

SAP2012:

- Refers to the 'Green Deal Occupancy Assessment Methodology' [Ref.10] to be published in summer 2012.
- The shower flowrate is provided as 11 l per min and the shower duration at 6 min.
- This would result to a shower water volume of 66 l per showering event.

SAP 10/10.1

According to the SAP Consultation Paper: CONSP:08 [Ref.11] individual showers should be allocated individual flowrates to estimate hot water use in SAP10/10.1.

The consultation paper provides the following information in the form of a table:

Table 13 - CONSP:08 Shower flowrates

Proposed flow rates (l/min) for plumbing arrangements (l/min)	
Vented hot water system	7
Vented hot water system + pump	12
Unvented hot water system	11
Instantaneous electric shower (vented or unvented)	0

As referenced within the Future Homes standard '*The minimum recognised rate for showers has been set to 8l/min for new homes, or 7l/min for existing homes*.' [Ref.13].

The 'Green Deal Occupancy Assessment Methodology', 2014 [Ref.10]

The uploaded BRE technical document was used for to advise SAP2012. The posted document refers to: '*RdSAP 2012 version 9.92: Occupancy Assessment version Mar 2014 (document dated 10 December 2014)* '. No other version of the document was identified online.

The daily domestic hot water use is calculated using the following formula:

Vd,average (litres/day) = Vd,shower + Vd,bath + Vd,other

where

- Vd,shower (litres/day) = Showers per day × hot water per shower from *Table V1*
- Vd,bath (litres/day) = Baths per day × 50.8
- Vd,other (litres/day) = 9.8 N + 14

As referenced within the paper Table 14 provides estimates of hot water used per shower (volume in litres without specifying neither the flowrate nor the duration).

Table 14 - Table V1 of the Green Deal Occupancy Assessment Mythology

Shower Type	**Hot water used per shower (litres)**
Mixer – not combi	28.8
Mixer - not combi, and electric	14.4
Mixer – combi	44.4
Mixer (combi)* and electric	22.2
Pumped	43.5
Pumped and electric	21.8
Unknown *Unknown based on shower ownership of 27.2% mixer (not combi), 9.8% mixer (combi), 15.1% pumped, 47.9% electric*	18.7

It is not very clear what is meant by the 'and electric'. It is assumed that this refers to an additional electric shower present. Therefore, half of the hot water is allocated to the actual non-electric mixer shower.

The following relationships between the number of occupants' showers and baths are supplied:

- Showers per day = 0.45 N + 0.65
- Baths per day (shower also present) = 0.13 N + 0.19
- Baths per day (no shower present, i.e. "None" selected in Table V1) = 0.35 N + 0.50
- Other: $V_{d,other}$ =9.8 + 14

Note: The same formulae appear within the Appendix J for the SAP10/10.1 DHW calculation process but with some modifications around volume of water calculations as discussed later in the report.

Table 15- Summary of information as shown in different versions of SAP [Ref.8]

SAP Version / Technical Document	Shower Flowrate	Shower Duration	Vmix
SAP2005	Not indicated but for the WWHRS (**NEN5128 A1:2009**) tests 7.5l/min is used	Based on 7.5l per min the shower duration could be calculated to be 10mins	Fixed 75l per shower
SAP 2009	'η' is the average efficiency of showers in the dwelling, The function utilises a flowrate of 9l/min for its estimation	Based on 9l per min the shower duration could be calculated to be 8.3mins[3]	Fixed 75l per shower (maintained from SAP2005)
SAP 2012	11l/min consultation version of SAP 2012	6mins consultation version of SAP 2012	66l per shower
SAP 10 CONSP:0.8	Provides different levels of flowrates but as indicated in the document '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.	6mins	48l per shower if the 8l per minute is used
PartG 2015 edition [Ref.17]	The estimated water consumption of a new dwelling should be calculated in accordance with the methodology set out in Appendix A, referred to as the water efficiency calculator. **As an alternative to calculating the water consumption (as paragraph 2.2), a fittings approach that is based on the water efficiency calculator methodology may be used.** Maximum fittings consumption 10l/min Maximum fittings consumption **optional** requirement level 8l/min	6mins	Maximum fittings consumption 60l Maximum fittings consumption **optional** requirement level 48l
Future Homes Standard Consultation	The minimum recognised rate for showers has been set to 8l/min for new homes, or 7l/min for existing homes	6mins	48l
NHBC Standards 2019 [Ref.18]	Table 3. The recognised rate for showers design flowrates is at 12l/min for new homes. 6l/min is the minimum flowrate of the shower when multiple outlets are open. Table 4. Minimum acceptable boiler output 9l/min	N/A	N/A

NEN5128 A1:2009 [Ref.19]

'*The efficiency of a DWHR is the ratio of the actual heat transferred to the maximum heat that could possibly be transferred from one stream to the other. For Europe, the NEN5128 A1:2009 norm published 1-May 2009 (correction letter 26-Jun 2009 from TNO) prescribes performance testing for DWHR systems for shower*.'

'*The test is based on a shower cabinet with no occupants, **40°C shower water temperature, 10°C cold water temperature and two flow settings, respectively 9.2l/min and 12.5l/min**. The flow is balanced meaning that the cold-water flow equals the drain water flow (equivalent to an installation scheme feeding both shower valve and water heater). In the test certificate, the efficiency of the unit is reported as well as the pressure loss across the cold-water connections at the given flows*. '[4]

According to information received from WWHRS suppliers in the UK, currently the methodology the BRE is using to adjust the performance of the WWHRS, is to interpolate the efficiency from the NEN128 A1:2009 to 9l/min. Recently this was changed to 11l/min in SAP2012 but SAP10/10.1 will allow for low flowrates to be specified and the impact of that on the efficiency of the systems used is still unknown.

Irrespective of the WWHRS efficiency calculations, the shower flowrates directly affect DHW calculations within SAP.

Figure 11 provides information extracted from SAP and literature review data in terms of showering volumes per event.

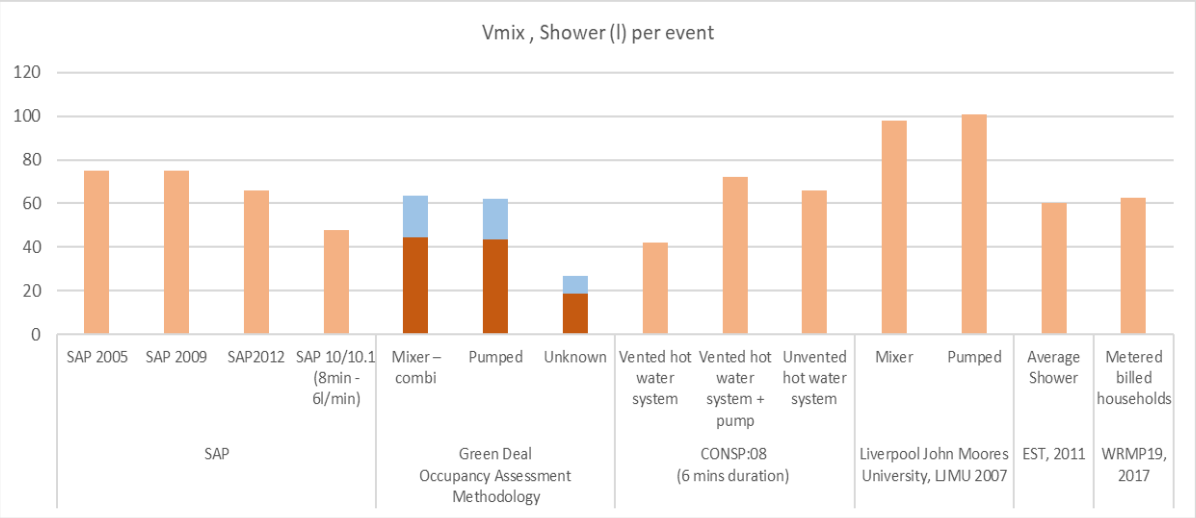


Figure 11 – Shower volumes as shown and provided from different resources commonly referenced within the different SAP versions

3.3.1.1 Showering and Bathing habits

SAP and Literature review

The following information was extracted from Ref. 8:

- SAP 2005/2009: Showers are used 1.86 times a day and baths 1.17
- SAP 2005: shower volume 75 l consumption (water mix) and bath 68.55 l per event

[4] http://www.meanderhr.com/report/meanderhr_com_shower_dwhr_overview.pdf

- SAP 2009: shower volume 75 l consumption (water mix) and bath 68.55 l per event (unchanged)
- SAP2012: shower volume 66 l consumption (water mix) and bath 50.8 l per event
- SAP2012: number of showers per day changed from 0.7 (2005/2009) to 0.73 per person (4.9 to 5.11 showers per week)
- SAP2012: number of baths per day changed to 0.21 per person per day (or 1.47 baths per week)
- SAP2012: number of 'bathing events' per week therefor was ~6.6 per day
- SAP2012: fraction of hot water (F_{ba} in SAP) used for showering and bathing changed from 0.66 to 0.61.
- SAP 10/10.1: The number of showers/baths per person per week is provided through occupancy-based functions:

Number of showers per person per day: (0.45*Nocc+0.65)/Nocc – if there is also a bath

(0.58*Nocc+0.83)/Nocc – if there is no bath

Number of baths per person per day: (0.13*Nocc+0.19)

The following data was extracted from literature information:

- WRc 2007 [Ref.20]: Average value of frequency of use 0.7 showers per person per day (large spread), 90th percentile at 1.30 showers per day)
- Liverpool John Moores University 2007 [Ref.20], LJMU home-based evaluation, 0.70 showers per person per day for pumped showers, and 0.99 showers per person per day for mixer showers.
- EST 2011 [Ref.14], Measurement of domestic hot water consumption in dwellings, the mean household consumption has been found to be 122 litres/day, with a 95% confidence interval of ±18 litres/day. Number of children had a 67% probability to influence hot water consumption
- EST 2013 [Ref.15, at Home with Water, a person uses 142 l of water per day and 25% goes to showers. Each individual takes 4.4 showers and 1.3 baths each week (or 0.63 showers a day and 0.18 baths)
- EST 2015 [Ref.16], At Home with Water 2 notes: '**We can have greater confidence in observations when identifying showers and baths combined as "personal bathing" events, rather than separating the two**.' and reports 5.4 events per person per week (or 0.77 events per person per day)
- WRMP19 Household consumption forecast: Baseline forecast, 2017 [Ref.21], shower volume from 2015/16 metered billed households – volume per use 62.36l, frequency of use 0.86 per day (bath 0.24 per day)

The number of showering events noted from both SAP and the literature review research are noted in *Figure 12*.

SAP shower duration and flowrates are visualised in *Figure 13*. Literature review flowrate information is summarised in *Figure 14*.

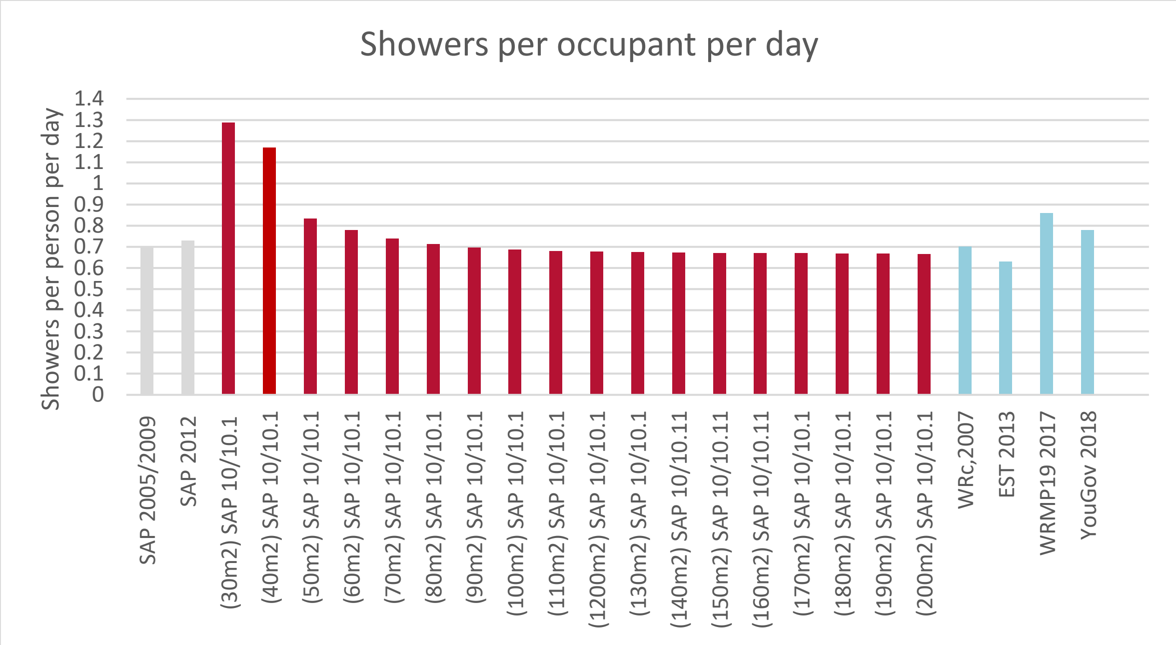


Figure 12 – SAP and Literature review – frequency of showering per occupant per day

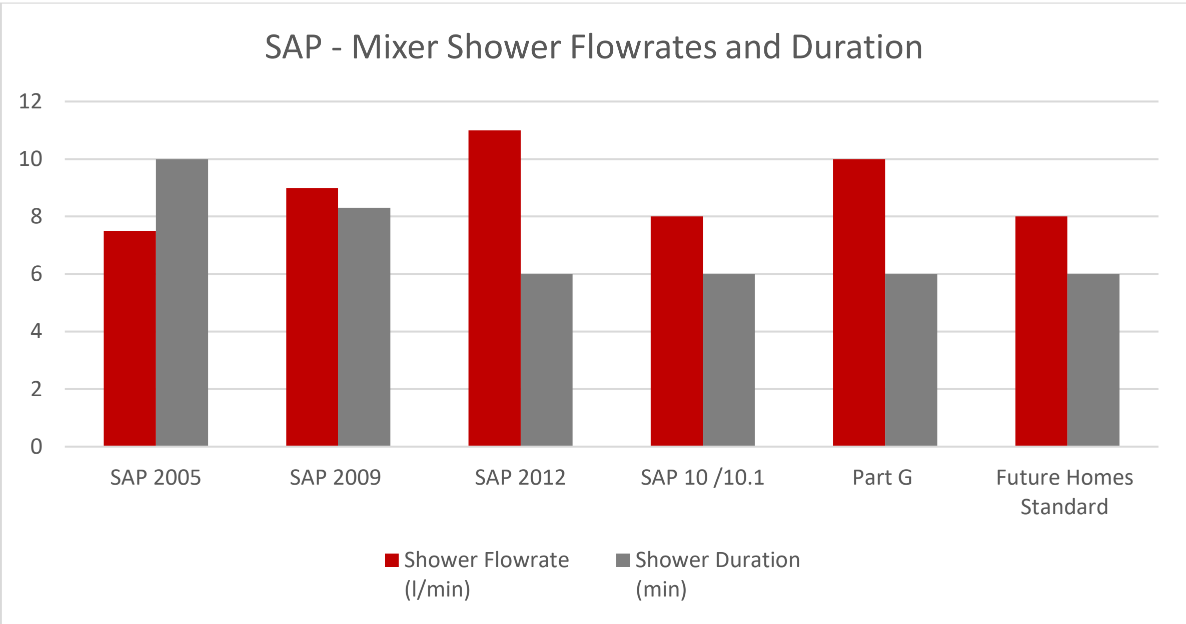
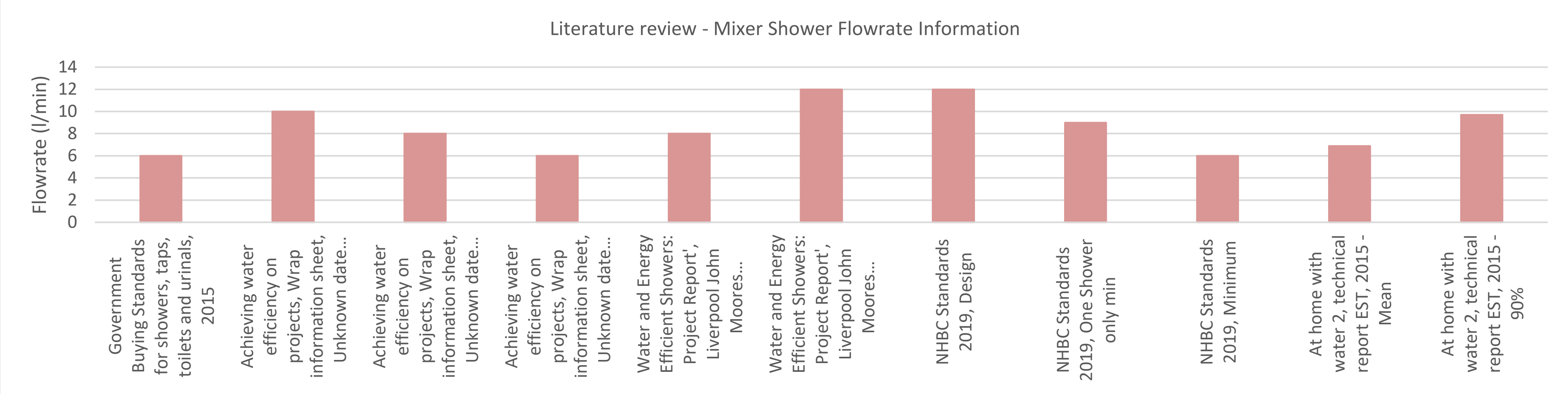


Figure 13 - Shower water volumes for different versions of SAP. In addition as calculated from the Green Deal Occupancy Assessment Methodology based, (70% hot water, 30% mains). CONSP:08 for SAP10 and later are based on a 6min shower duration.



Data Source	Showering Duration Reported (mins)	Comments
Mirashowers, based on YouGov data[5]	Men Average 7 Women Average 8 18-24 Average 11 1/2	Sample size 2061 adults, fieldwork between 19-20/04/18, online survey - Cost and water savings main reasons for reducing showering time
Water and Energy Efficient Showers: Project Report', Liverpool John Moores University, 2007	Av Mixer 9.5	Sample sizes vary based on the level of data granularity the research was trying to achieve. Short shower durations of ~6 were reported too
EST, At Home with Water 2, 2015	Mean, 6.9 mins 90%, 9.7	Based on 35 observations, the previous EST At Home with Water, 2013 indicated that ~55% will use the shower for more than >6 mins
UK sustainable shower study, Unilever,2011	Average: 8 Teens: 10+	100 families over 10 days, 2600 showers taken recorded
EU Commission, MEErP Preparatory Study on Taps and Showers , 2014	Average: 7	Value is supported by studies on the use of shower in Portugal and the UK (UK is the EST At Home With Water 2013

Figure 14 – Literature review – shower flowrates combined data

[5] https://www.mirashowers.co.uk/blog/trends/revealed-what-brits-are-really-getting-up-to-in-the-bathroom-1/

3.3.1.2 SAP Predicted compared to literature review information

Shower Flowrates

Using an energy efficiency flowrate of 8l/min in SAP is substantiated by various guidance documents focusing on energy and water efficiency targets.

Nevertheless, it has been indicated that low shower flowrates (6-8 l/min) may impact the user satisfaction during the showering event [Ref.22].If showerheads are not appropriately designed to ensure the 'experience' of the users, devices such as flow restrictors might be removed or shower durations increased.

Shower Duration

The shower duration was noted to vary greatly between the different demographics. Whilst the exact features of the showering experience (see flowrate, pressure and type of showerhead) appear to be of importance, other considerations such as cost and water savings have also been noted through the research review. Resources examined appear to on average note a shower duration of 7-9 minutes being the 'most' common.

Shower Volume

The volume of water used for the individual showering event can be estimated by multiplying an average showering event duration with the flowrate of the shower. Therefore, the two variables can be used for its prediction. A range of 60-100 l per showering event appears to be common. It needs to be noted that with a shower flowrate of 8l/min and a duration of ~8mins a shower volume of 64l per showering may constitute a good approximation (on the lower end).

Shower Behaviour

Focusing on showering habits and frequency of use, literature review information appears to demonstrate a good alliance with SAP predictions (~0.7 showers take per person per day).

SAP 10/10.1 proposed methodology also returns similar values for a range of TFA and number of occupancy levels tested (TFA 30-100m^2).

A summary of findings includes:

- A flowrate of 8l/min for showers appears to be reasonable and in alignment with information reviewed within the literature review. Lower flowrates and the expectation that installed flow restrictors will remain installed are questionable.
- A duration of 6mins per shower appears to be low, with information collected indicating that a duration of 8mins could be closer to the 'common' people preference. Further research will be required to substantiate a 6mins duration
- The volume of water used per showering event is a product of showering event duration and the shower flowrate.
- An assumption of around 0.7 showers per person per day appears to be reasonable even though it heavily relies on demographics and therefore can greatly vary.

4. SAP WWHRS Energy Savings Calculations

4.1.1 SAP 2012 and SAP 10/10.1 methods (Instantaneous WWHRS) Energy Savings

According to information received by ReCoup.

Requirements of L1a and L1b in the consultation draft provide details of minimum expected standards for hot water with respect to heat losses (pipe work and stored hot water), time and temperature controls. In regard to L1a, section 4.16 provides details on the maximum accepted heat losses from cylinders in order to provide limited heat losses. An average cylinder size for a 3-5 bedroom house is between 150-250 litres. Table 4.3 gives heat losses for this range of 1.88-2.22 kWh/24h.

Based on 6 minutes and 8 litres/min as the minimum energy used for showering per occupant, this works out to 1.5 kWh of energy per shower with approx. 1.23 kWh still in the waste shower water as it leaves the building. If occupancy is calculated at 2.3, this is 2.83 kWh of energy for all occupants showering and based on an average shower frequency of 0.8x per day, would be 2.26 kWh per 24 hours which is higher than the cylinder minimum standard.

Given that for the cylinders, this heat loss in certain months of the year would be actually contributing to the heating of the actual dwelling (potentially 6 months of the year) there is twice as much energy being lost through the waste pipework as there is from a cylinder. If we consider 7.5 minutes per shower (as per EST research) and 11 litres/min (standard in SAP if no adjustment made) this increases to 2.6 kWh per shower with 2.13 kWh being lost from the building through the waste pipes. For 2.3 occupants this is 3.92 kWh per day.

Potentially 4x as much energy is lost from the building via the waste pipe (waste pipes could be considered as part of the buildings fabric) as is lost from a cylinder (assuming 6 months is contributing to the dwellings heating) over a 24-hour period. The requirements under L1a and L1b for heating are understandably still being increased to keep minimising energy use and are backed up by the increasing fabric requirements of the dwelling. However, despite hot water now requiring a similar level of energy per dwelling, the hot water standards do not appear to have this 'fabric' back up to support the minimum standards to limit the heat losses from the building with regards to hot water.

Two sample properties were trialled in SAP in terms of predicted WWHRS savings in order to compare the SAP2012 method to that used within SAP10.1 *Table 16*.

It needs to be noted that currently the SAP10.1 software available is not expected to be used for compliance purposes. As it only exists as a demonstrator of the type of methodological changes expected, results might be incorrect or inaccurate if errors are identified within the process.

Table 16 - DHW Energy Consumption and WWHR savings, Monthly Averages (kWh/month) for two sample properties

Number of bedrooms	TFA - (m^2)	SAP2012 (kWh/month)	SAP10.1	SAP2012 WWRS Savings	SAP10.1 WWRS Savings
2/3 Bedroom	78.9	92.2	119.4	**33.1**	**35**
4 Bedrooms	125.6	102.7	132.9	**38.1**	**39.0**

Main observations:

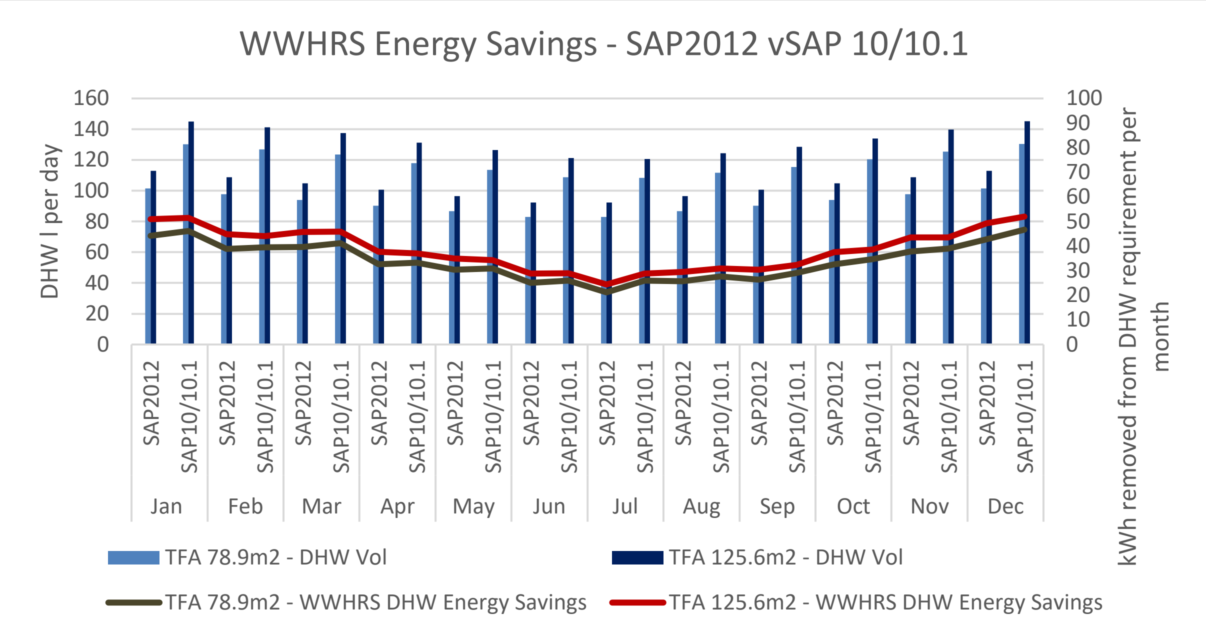


Figure 15 - WWHRS Energy Savings SAP0212 and SAP10/10.1

A summary of findings includes:

- The SAP DHW methodology and the way savings are calculated from the WWHRS went through fundamental changes within the SAP10/10.2 methodology
- The complexity of the process and the way the data interlinks (DHW SAP calculation and savings allocation due to WWHRS) create confusion in terms of numbers of variables used and where such information comes from
- Changes occurred within the temperature assumptions of the mains within the new SAP and showering temperature was reinstated to 41dc (rather than 40dC SAP2012) see Appendix A
- DHW calculations are dictated by occupancy assumptions and predictions in terms of the user behaviour
- In two sample properties tested the DHW daily requirement increased by almost 30%
- For the smaller (78.9m2) property the WWHRS savings from moving from SAP2012 to SAP10/10.1 was estimated to be 6%
- For the larger property (125.6) the WWHRS savings from moving from SAP2012 to SAP10/10.1 was estimated to be 2%
- WWHRS energy savings were calculated using the SAP10.1 online tool so results presented should be reviewed against the official SAP10.2 or later approved software tool

5. Other areas of concern

5.1 Utilisation of showering/bathing facilities in new residential with more than one showers

SAP is calculating the amount of hot water used in each shower based on the flowrate specified. WWHRS will recover energy from the showers they have been installed on. Energy savings are assigned based on the assumed level of utilisation of the shower where the system is installed.

Currently all showers are assumed to be following the same behavioural pattern. What is not clear is if there could be a behavioural factor involved as to whether or not the residents would prefer to use the shower that produces the maximum cost savings. In that case, the energy savings from WWHRS would be underestimated. Conversely, if the shower where the system is installed is never used, no savings will be achieved.

Behavioural factors in terms of showering/bathing habits are hard to predict. They can vary based on the space's layout, changes in the lifestyle of the occupants, changes in occupancy levels, age of the occupants and other factors.

A mandatory requirement for all showers to be connected to a WWHRS or similar passive domestic hot water heat recovery technologies could simplify some of the process.

5.2 Additional losses for combi boilers not tested to EN 13203-2 or OPS 26

It was noted that Table 3a: '*Additional losses for combi boilers not tested to EN 13203-2 or OPS 26*' provides the following function for Storage combi boiler**, store volume Vc < 55 litres

[600 – (Vc – 15) x 15] × fu × nm / 365

If the daily hot water usage, Vd,m, is less than 100 litres/day, fu = Vd,m / 100, otherwise fu = 1.0

Nm: number of days per month

For a Vc of 15l the losses would be 600kWh. / year. Whilst this could be correct, it is advised that the evaluation method is reviewed as losses appear to be substantial. It needs to be noted that Vd,m in the models produced for properties 40-200m^2 starts marginally being more than 100l/day at a property of 55m^2.

In most cases an fu = 1.0 will apply disassociating the losses from the actual hot water use (which by default is linked to the TFA).

5.3 All electric solutions – peak demand

With ambitious government plans in place to cut down emissions deriving from new homes, and an ambition to move to technologies such as heat pumps for heating purposes,[6] a question is raised in terms of current SAP DHW methodology and assumptions (occupancy, showering habits, energy and volume of water used).

With heat pumps having a lower Coefficient of Performance (COP) for DHW (most products) and the electricity remaining at a high cost to the consumer in the future, the contribution of passive technologies such as the WWHRS should not be underestimated.

Savings achieved are not only translated in terms of affordability to run, but in addition can reduce the peak load demand on the electricity grid, at times of the day of increased DHW demand.

[6] https://www.gov.uk/government/news/housing-secretary-unveils-green-housing-revolution

SAP assumptions and methods may require re-evaluation so the take-up of WWHRS is not hindered due to ‘gaming’ and inherited inaccuracies of the tool.

From a lifecycle perspective, a WWHRS with no moving or mechanical plants or refrigerants, provides a robust long-lasting building ‘fabric’ like solution.

6. Conclusions and Observations

- The research activities included the review of historic, current and proposed SAP processes and methodologies in terms of predicted levels of occupancy and DHW demand calculations. It included the review of both the formulas used within SAP as well as the reference documents used to produce the methods.
- Census 2011 and literature review data indicated that the current SAP methodology, estimating the levels of occupancy based on the total floor area of the property may require adaptations to avoid over or underestimation of DHW use in new homes.
- Changes in the calculation method of DHW in SAP10/10.1 led to an overall increase of around 30% in terms of DHW demand per day (for currently suggested showering parameters)
- If the current methodology is accurate, the levels of occupancy may require adjustments to address concerns around actual DHW daily consumption and avoid unnecessary calculation complexities. Potential sensitivities were identified in the DHW calculation based on occupancy predictions for 3B and 4B homes with potential impact expected to be exemplified by the fact that they can constitute ~66% of new homes delivery.
- A question is raised as to whether or not the SAP method should be adapted to utilise the number of bedrooms as a potential indicator for the calculations of the occupancy levels rather than TFA. It could be more appropriate as number of occupants are more likely to be dictated by the number of bedrooms. Ranges for floor areas could also be introduced to convert TFA to number of bedrooms requiring confirmation from the SAP Assessor.
- The 5% decrease in <125l of water consumption per person per day is applied to the calculation method even though the actual predicted DHW showering volumes are based on the flowrate and the durations of showering, (this is already noted within the method). It is unclear why a further reduction is applied in the form of a % decrease.
- It needs to be noted that with a number of SAP parameters and the method approach simultaneously changing, a clear track record of changes along with reference information substantiating the approach will need to be provided by BRE
- It is recommended that additional research is undertaken to confirm the applicability of the new recommended SAP 10.1 DHW calculation approach in different property types
- A flowrate of 8l/min for showers appears to be reasonable and in alignment with information reviewed within the literature review. Lower flowrates and the expectation that installed flow restrictors will remain installed are questionable.
- A duration of 6mins per shower appears to be low, with information collected indicating that a duration of 8mins could be closer to the ‘common’ people preference. Further research will be required to substantiate a 6mins duration
- An assumption of around 0.7 showers per person per day appear to be reasonable even though it heavily relies on demographics and therefore can greatly vary.
- The complexity of the process and the way the data interlinks (DHW SAP calculation and savings allocation due to WWHRS) creates confusion in terms of numbers of variables used and where such information comes from
- WWHRS energy savings were calculated using the SAP10.1 online tool so results presented should be reviewed against the official SAP10.2 or later approved software tool
- Analysis of NDSS data and anonymised national housing typologies information indicated a good alignment between NDSS TFA to the number of bedrooms relationship. That relationship was used to analyse the predicted levels of occupancy between SAP and Census 2011 data.

Recommendations

The re-examination of the proposed SAP10/10.1 methodology with regards to occupancy levels predicted for new homes, as well as the relationship between number of occupants and DHW consumption predicted **is strongly advised**. The DHW demands could be disassociated from the TFA and potentially linked to number of bedrooms which might offer a better representation of occupancy levels. At the same time, it would allow for the alignment of metrics used in Census analysis and market reports (commonly referring to the number of bedrooms).

Furthermore, the re-evaluation of the showering duration time, in light of the impact that such changes might have on passive energy saving technologies such as WWHRS, should be re-evaluated.

It is of critical importance that the method itself does not hinder or underestimate the impact of passive technologies such as the WWHRS in delivering the required environmental, energy and carbon targets from new housing.

SAP 10/10.1 WWHRS and DHW calculation methods need to be clear and transparent as to how the method works, with appropriate supportive clear and well documented technical resources published. Inherited, out of date and potentially small sample based empirical data used within the methodology needs to be singled out and re-examined.

Please also refer to the 'Other Areas of Concern', to note additional concerns in terms of the SAP impact on journey to an energy efficient, low energy demand and net-zero carbon potential implications.

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Appendices

Appendix A - WWHRS Savings SAP Calculation Methods Summary

7.1 The SAP manual instructions

The following instructions are presented within the different versions of SAP in terms of calculating WWHRS savings.

7.1.1 SAP 2009 – SAP 2012 and SAP 10/10.1 methods (Instantaneous WWHRS)

SAP 2009

1. Obtain the utilisation factor (UF) and heat recovery efficiency (η) for mixer showers from the database record for each system installed and calculate the average system effectiveness according to equation (G9).

Seff = [Σ (Nsh&bth × 0.635 × η × UF)$_{1,2}$ + Σ (Nshxbth × η × UF)$_{1,2}$] ¸ Nbth+sh (G9)

2. Calculate the savings (kWh/month) for mixer showers with WWHRS according to equation (G10).

Sm = [N × Aw,m + Bw,m] × Seff × (35.0 - Tcold,m) × 4.18 × nm × MFm : 3600 (G10)

Aw,m = [0.33 × 25 × DTm : (41 – Tcold,m)] + 26.1

Bw,m = 0.33 × 36 × DTm : (41- Tcold,m)

SAP 2012

1. Obtain the fraction of bathing waste water that is routed through the heat recovery system (Fww), the utilisation factor (UF) and heat recovery efficiency (η) for mixer showers from the database record for each system installed and calculate the average system effectiveness according to equation (G9).

Seff = [Σ (Nsh&bth × Fww × η × UF)$_{1,2}$ + Σ (Nshxbth × η × UF)$_{1,2}$] ¸ Nbth+sh (G9)

2. For each month calculate the savings (kWh/month) for mixer showers with WWHRS according to equation (G10).

Sm = [N × Aw,m + Bw,m] × Seff × (34 – Tcold,m) × 4.18 × nm × MFm : 3600 (G10)

where:

- if the dwelling is designed to achieve a water use target of not more than 125 litres per person per day (all water use, hot and cold):

Aw,m = [0.30 × 23.75 × DTm : (40 – Tcold,m)] + 23.8

Bw,m = 0.30 × 34.2 × DTm : (40 – Tcold,m)

- otherwise:

Aw,m = [0.30 × 25 × DTm : (40 – Tcold,m)] + 23.8

Bw,m = 0.30 × 36 × DTm : (40 – Tcold,m)

Tcold,m is the temperature of the cold water feed in month m (see Table G2)

nm is the number of days per month from Table 1a

MFm is the monthly hot water use factor from Table 1c

DTm is the temperature rise of hot water drawn off from Table 1d

N is the number of occupants as at SAP box (42)

Table G1 : Dwelling data required for Instantaneous WWHRS (system A, B or C)

Description of parameter	Symbol
Total number of rooms with bath and/or shower (any type, with or without WWHRS fitted)	N_{bth+sh}
Number of mixer showers fitted with $WWHRS_1$ in rooms with a bath	$N_{sh\&bth,1}$
Number of mixer showers fitted with $WWHRS_1$ in rooms without a bath	$N_{shxbth,1}$
Number of mixer showers fitted with $WWHRS_2$ in rooms with a bath	$N_{sh\&bth,2}$
Number of mixer showers fitted with $WWHRS_2$ in rooms without a bath	$N_{shxbth,2}$

SAP 10/10.1

Obtain performance data from the PCDB for each WWHRS present in the dwelling

2. Establish which shower outlets drain into each WWHRS (from SAP assessor inputs)

3. For each WWHRS, k, sum the monthly warm water volumes, Vshower,i,m (litres/month), from Appendix J, step 1j, for each relevant shower outlet to obtain the total volume of warm water draining into it, VWW,k,m (litres/month).

4. Calculate the heat content of the warm water draining to each WWHRS, QWW,k,m (kWh/month), with respect to the incoming cold water temperature for the month, Tcold,m (°C), from Table J1, assuming warm water reaches the WWHRS at a temperature of 35°C.

QWW,k,m = VWW,k,m × (35 – Tcold,m) × 4.18 : 3600 (G9)

5. Calculate the heat recovered by each WWHRS, Sk,m (kWh/month), by multiplying the heat available by the system's heat recovery efficiency, ηk, and utilisation factor, UFk, both taken from the PCDB data entry.

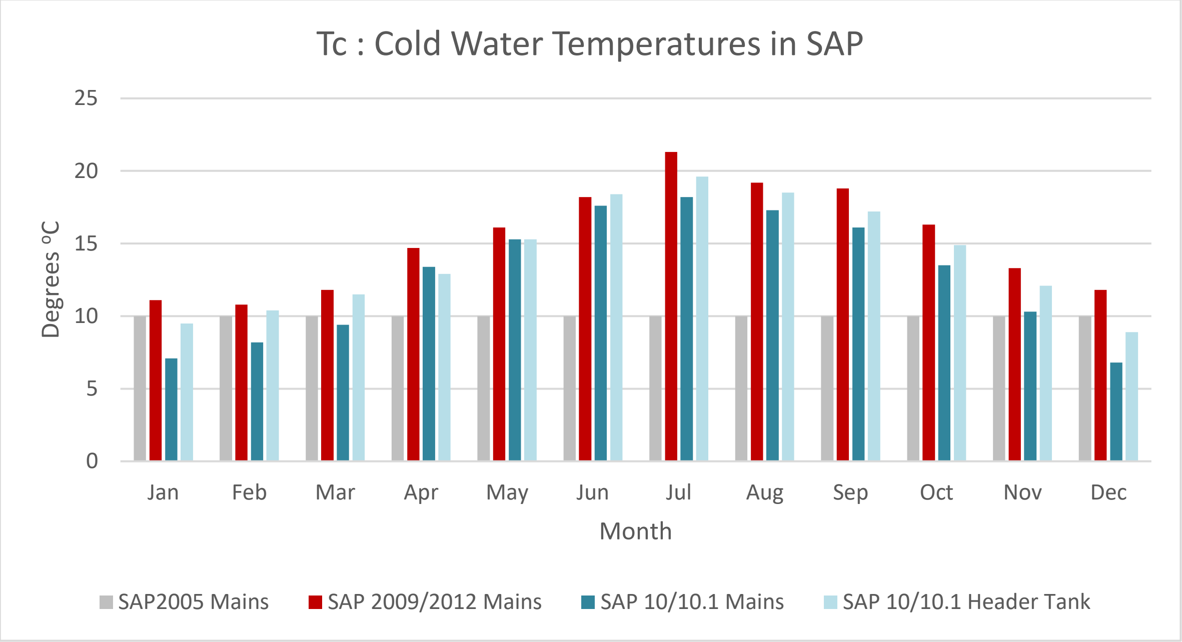
Sk,m = QWW,k,m × ηk × UFk (G10)

6. Sum the heat recovered by each WWHRS to give the total saving from WWHRS, Sm (kWh/month)

Sm = ΣSk,m (G11)

Main Comments

- All methods require the utilisation factor (UF) and heat recovery efficiency (η) of the WWHRS system – methodology not explored as part of this research
- Current SAP2012 method is an adaptation of the SAP2009 methods varied in terms of critical components such as the fraction of hot water used in the dwelling for showering and bathing (integrated within the Aw,m and Bw,m calculations [Fba])
- SAP2012 does not fix the SBmix (=0.635 within function G9) which is based on frequency of use per day and consumption per event rations between bathing and showering
- The drain temperature in SAP2012 (34 – Tcold,m) was changed from 35ºC in SAP 2009 to reflect the 6ºC reduction during showering and the reduction of the shower/bath water temperature from 41ºC (SAP2009) to 40oC (SAP2012). It appears that in SAP10.1 the 35ºC is reinstated.
- SAP 10/10.1 methods is clearer to follow as it indicates separate inputs for flowrates of showers and the hot water calculation method follows the guidance as presented within the CONSP:08
- In both SAP10 and SAP10.1 the cold-water monthly temperatures were updated with a note that the table will be revised when the new SAP is introduced
- The temperatures used for mains water was reduced by 0.8-5ºC depending on the month when compared to those currently being used within SAP 2012. Furthermore, temperatures from a header tank cold water supply were also included.



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WWHRS: Summary and overview of conversations

This document is a summary of previous discussions between Recoup Energy, Showersave (BPD Limited), BEIS and BRE in relation to WWHRS technology, its calculations within SAP and areas that we feel need urgent attention and consideration.

The following abbreviations will be used in the document (if required): -

BEIS – Department for Business, Energy & Industrial Strategy
DECC – Department of Energy & Climate Change
BRE – Building Research Establishment
RES – Recoup Energy Solutions Ltd
BPD – Showersave / BPD Limited
WWG – WWHRS working group – Recoup and Showersave/BPD Limited
ISD – Ian Steward – Director - Recoup Energy Solutions
TGN – Tony Gordon – Managing Director – Showersave / BPD Limited
KRD – Katy Read – BEIS - Policy Lead – Energy Performance of Buildings (Until end of May 2019)
JHN – John Henderson – BRE – Principle Consultant
TLN – Tone Langengen – BEIS – Policy Lead – Energy Performance of Buildings (From August 2019)
PNE – Peter Noyce – BEIS – Senior Policy Advisor – Clean Heat

Overview

The WWG have concerns on the current methodology for WWHRS calculations, along with historical changes that were made in previous consultations. Most of these have been previously discussed, but a few have recently come to light. The key areas will be covered in this document are: -

1. Shower duration
2. Shower flowrate
3. Shower frequency and behaviour
4. Occupancy calculation
5. Hot water standards

With each section, the WWG will aim to provide history of this area within SAP, our concerns and links to previous discussions and relevant research.

1. Shower duration

The calculations in SAP 2009 for WWHRS were based on a shower time of 7.9 minutes, but the SAP consultation released by DECC on the 4th January 2012 proposed a change of this to 6 minutes per shower (Page 16) –

> *'For the purposes of assessing waste water heat recovery systems (WWHRS), shower assumptions have been amended following review of the available data. The shower flow rate was 9.5 litres/minute and is now 11 litres/minute, shower duration was 7.9 minutes and is now 6 minutes, shower water temperature was 41°C and is now 40°C. These changes have a small effect on the savings from WWHRS.'*

Other changes in the above will be discussed later. However, a general note here is that these amendments in the consultation document appeared after the Q21 (Page 14). WWHRS is linked to the hot water system and all other proposed changes and questions relating to the hot water system were found on pages 11-12. Therefore, the 'other amendments' appeared on reading not to have an associated question, or at least, the associated question was not in an obvious position.

The summary of consultation responses do not make any reference to Q21. Having reviewed the *'Unattributed consultation'* questionnaire responses, those in section 31, 42, & 80 ask for further details on how the proposed changes were made. The WWG have also asked for the evidence/research that came to light between SAP 2009 and 2012 to support these changes, but this so far has not been provided, and no comment made to these requests on the consultation response.

It is the WWG's understanding that the 6 minutes per shower is taken from ''Green Deal Occupancy Assessment Methodology (DECC)' which was due to be published in 2012. However, we have still not been able to find this information and it has been requested on numerous occasions from BRE/BEIS. The link to Green Deal Occupancy Assessments (Based on SAP 2012), does not lead to any subsequent links to this research.

On 25th October 2012 - John Hayton produced a report evaluating the methodology behind WWHRS, well after the consultation responses were collected, in which the first part of the methodology references a value of 6.5 minutes per shower, but later concludes on page 15 that the value will be altered based on the results of the 'Green Deal Occupancy Assessment Methodology', DECC, (to be published in summer 2012) to 6 minutes.

The 6.5 min shower time based on 2 reports, where one report (12 July 2011 Dene Marshallsay, '*Understanding domestic water use in the context of demand management and forecasting'*, Wrc Plc; NOTE: The link for this that is provided in the John Hayton report is no longer working) reported average usage of 5.8 mins based on only 46 homes, included homes with electric showers, which are not used with WWHRS and John Hayton comments on this –*'The samples are therefore biased away from larger wealthier households'*; the other report (Potential water savings through the use of HL2024 shower flow regulator, Dr D B Sims-Williams, Dr H.A. Bulkeley, Dr Pc Matthews, Mr G D Powells, University of Durham, May 2008) was based on occupant measurement of 204 homes which showed 6.5 mins per shower. I have been unable to find a copy of this report, but it does seem associated with a commercially available product, rather than independent research.

Further consultation was then published regarding *'Amendments to SAP's hot water methodology'* Consultation Paper: CONSP:08. The WWG responded to this, highlighting the key concerns being raised in this document and provided what was believed to be substantial and relevant evidence. Despite requests for meetings to discuss further, none of the evidence or concerns raised have been responded to in detail, in terms of how the evidence/concerns put forward does not supersede evidence/research previously used.

It should be noted that the report - *'Water and Energy Efficient Showers: Project Report*', Richard Critchley, United Utilities and Dr David Phipps, Liverpool John Moores University. 2007, which is widely referenced in CONSP-08 - Hot Water makes reference to a WRc report of 233 homes (page 42) which also concluded a shower time of 5.8 minutes (I believe this report takes data from the study mentioned previously by Dene Marshallsay in the John Hayton report), based on 763 shower events from 43 homes. LJMU then report their own findings with an average shower time of 9.5 minutes (page 44) and an average shower frequency of 0.87 per person (0.7 reported by WRc). Based on the frequency and two-week period of reporting, this would be in the region of 377 shower events (14 days x 0.87 x 31 (No. of People)).

The authors of the LJMU study state: -

> *'The reason(s) for the difference are unclear: it is thought likely to be because people with mixer or pumped showers stay under the shower for longer, or because people are now spending more time in a shower than when the WRc monitoring took place. Other possible contributory reasons could be the small size of the LJMU sample or that these customers changed their behaviour and increased their shower duration after fitting of the water saving device'.*

Key points from this statement: -

- It notes the difference possible in duration between mixer showers and electric showers
- Potential difference in the economic status of the households. As noted by John Hayton, the WRc study was of low-income households.
- Potential behavioural change due to lower flow rates. (This should be noted and will be discussed later in section 2).

Research supporting a change to shower time back towards the original value of 7.9 minutes in SAP 2009 includes: -

Energy Saving Trust – '*At Home with Water*' (Pages 18-20) - Surveyed 86,000 homes - Average shower time of 7.5 minutes was reported. EST also produced a subsequent document '*at home with water 2: technical report*'. Pages20-21 of this report compare observed to perceived shower durations in order to identify any differences. The average duration of the observed results was 7.7 minutes compared to the 7.5 minutes of self-reported times.

A study by Unilever - http://www.bbc.co.uk/news/science-environment-15836433 - study of 2,600 showers by 100 families in 2011 reported an average shower duration of 8 minutes.

A report prepared for the European Commission '*MEErP Preparatory Study on Taps and Showers'* (2014) reports after assessing all available information a shower duration of 7 minutes (Section 3.6.1; Page 140).

Back in 2009, there was research carried out by Waterwise which fed into their Shower Power campaign to reduce shower times. The research is no longer available on the Waterwise website, but we are sure it could be requested. Values reported in the media at the time were an average of 10 mins per shower for men and women, but the dataset at this time is unknown.

Shower duration summary

It was reported in the consultation paper from 2012 that he changes proposed to the WWHRS calculations would result in very small change. Whilst this might have been true based on overall volume of water used (duration vs flow rate) due to changes in flow rate, the proposed new changes in SAP 10 will now magnify this change considerably from SAP 2009. The reduction of shower time from Sap 2009 (7.9 minutes) to SAP 2012 onwards (6 minutes) represents a 24% reduction to which the WWG have not seen substantial evidence for.

Even the John Hayton report of WWHRS methodology suggested 6.5 minutes (18%) reduction, however, with the details above (LJMU, EST, Unilever etc.), 6 minutes is certainly not the average that is coming out from this research, instead the value reported by the Energy Saving Trust (7.5 minutes) appears to be in the correct area.

An extra 1.5 minutes per shower, per person (based on 2.4 people per dwelling) per day (based on 0.7 showers per day per person) and a flow rate of 9 litres/min (as reported in SAP 2009 and not 11 l/min in 2012 onwards, as we believe this is closer to what is installed in new homes) works out to approximately 200 kWh extra per year per dwelling. Based on 300,000 new homes being built per year, this is approx. 164,000 kWh per day and 60M kWh extra per year. Critically, showering tends to be a peak demand habit and with the proposed changes to our energy supply over the next 30 years towards the 2050 target, this is a massive extra load on top of what is currently calculated.

2. Shower Flowrate

The calculations in SAP 2009 for WWHRS were based on a shower flowrate of 9 litres/minute, but the SAP consultation released by DECC on the 4th January 2012 proposed a change of this to 11 litres/min minute per shower (Page 16) –

> *'For the purposes of assessing waste water heat recovery systems (WWHRS), shower assumptions have been amended following review of the available data. The shower flow rate was 9.5 litres/minute and is now 11 litres/minute, shower duration was 7.9 minutes and is now 6 minutes, shower water temperature was 41°C and is now 40°C. These changes have a small effect on the savings from WWHRS.'*

We are not sure why the above states 9.5 litres/minute as the methodology document states 9 litres/min (Page 12).

With regards to flow rate that is allowed, there are some critical areas to consider: -

- Satisfaction and acceptance of a 'perceived' reduction in performance and experience
- Alignment with other policies and requirements
- Compliance

Satisfaction and acceptance of a 'perceived' reduction in performance and experience

The initial proposed changes in SAP 10 and linked to the new Part L regulations would have allowed an energy assessor to recommend a simple flow restrictor to be used and reduce the shower flow rate down to 6 litres/minute. Effectively making the flow restrictor an '*Energy Saving Device*', to which the WWG feel has the potential to lead to misuse and removal following its installation.

For a product to be recognised as energy efficiency measure according to SAP Appendix Q application process, it states that: -

> *Energy Efficiency vs Energy Reduction Measures*
>
> *Energy Efficiency Measures are defined as those that provide the same level of building service whilst reducing dwelling energy use. For example a condensing boiler enables the same level of heating service to be provided with less energy than a non-condensing boiler.*
>
> *Energy Saving Measures are defined as those that help occupants use less energy when they are willing to tolerate a lower level of building service. For example, a temperature controller may allow a heating system to adjust internal temperatures below standard SAP assumptions. These measures are not recognised by SAP, and depend on the extent to which occupants are willing to use them.*

A flow restrictor is reducing the flow rate of the shower down to levels that has no or little evidence (that the WWG can find) to demonstrate that occupants will be willing to use for the longevity of the dwelling. The WWG appreciates the changes made in SAP 10.1, stating a minimum flow rate that can be modelled of 8 litres/min rather than 6 litres/min.

There is evidence that users are not willing on mass to accept changes of behaviours that are put upon them with regards to showering, especially which result in a change in experience or perception, and these are discussed below.

'*Water and Energy Efficient Showers: Project Report*', Richard Critchley, United Utilities and Dr David Phipps, Liverpool John Moores University. 2007. In section 5 of the research, the impact of flow restrictors and aerated showerheads were assessed in a small sample of households (n18).

Both interventions resulted in average flow rates of the homes being reduced from 12 litres/min to 7.5 litres/min, with 6 of the 9 households asking for the device to be removed at the end of the study and 8 out of the 9 having a lower satisfaction score after the restrictor was fitted.

'*Patterns of water: the water related practices of households in southern England, and their influence on water consumption and demand management*' Pullinger, M., Browne, A., Anderson, B. and Medd, W. (2013). The research looked at responses from 1800 households in the South and South East of England. Water and energy-efficient water using technologies were rare, with only 1% of respondents reporting have fitted an aerated shower head or taps being fitted (Executive summary Page iii). This demonstrates that there is a very large 'unknown' to the acceptance of these devices and that they have not been proactively fitted by homeowners in the past.

Research carried out by Adeyeye et al. (2017), '*Design Factors and functionality matching in sustainability products: A study of eco-showerheads*' and Sousa et al. (2018), '*Showerheads experience: Statistical analysis of individual behaviour of the users'* (both are attached with this response) looked at various shower head designs, and user experiences. The sample sizes are small but the authors acknowledge this but highlight that there is limited research in this area.

The research highlights that there are many aspects to a consumers 'perceived' level of shower experience. The shower heads used varied in flow rate and even though classed as 'eco', only one had a flow rate lower than 6 l/min with the majority around 8 litres/min. The work presented at the Water Efficiency Conference in 2018 also supports section 1 argument with regards to shower duration, with average shower time being over 10 minutes, and even with the users 3,4 & 5 removed from the average, duration is still over 7 minutes per shower, however, there will always be this range of times across the population.

Work presented by Pimentel-Rodrigues & Silva-Afonso (2012) '*Water efficiency of products. Comfort limits*' looked at comfort levels for subjects from their 'normal' levels of flow rates/durations to the lowest perceived comfort level. A few key results come out from this (again, acknowledging the low subject number). Shower duration was on average 7 minutes, but crucially, this was seen to rise as flow rate was reduced. There are still energy/water savings made, but the authors highlight that these will not be as low as expected due to increasing shower time. Across the subjects, the average results were a flow rate of 6.4 litres/min and shower time of 7.6 minutes resulting in a volume of 48.6 litres of water used. SAP 10 would allow energy assessors to effectively prescribe a 36 litre shower (6mins x 6 litres/min) which is 25% lower than what was deemed acceptable in this study.

Finally, attached is the chapter *'Distributed demand and the sociology of water efficiency'* taken from the book '*Water Efficiency in Buildings'* edited by Kemi Adeyeye. The WWG will not go into detail here but believe that this chapter and its references really highlight the complex and multifactorial reasons to why 'we' shower and experience we expect. Water efficiency application to showering is very different to that of something like dual flush toilets, as it will directly impact experience.

Potential impact of flow restrictor removal

Based on a dwelling lifetime of 40 years an 8 litre/min shower in a home of 2.4 people each showering for 6 minutes (0.7x per day) would result in approx. 39200 kWh of energy being used.

If flow rate was increased from the start to 9 litres/min for calculations (as per the original SAP 2009 calculations), this would be approx. 41800 kWh over 40 years, an additional 2600 kWh.

If the flow restrictor in scenario 1 was removed at any time, on mains pressure this is likely to result in a shower flow rate of approx. 12 or more litres/minute (The minimum requirement of NHBC).

If this occurs any time before 37 years of the dwellings life, the net result of energy use compared to scenario 2 will be greater.

Alignment with other policies and requirements

The NHBC are one the largest provider of warranties to new build domestic dwellings in the UK. According to their website providing warranties to approx. 10,000 builders and developers for the first 10 years of a new build dwelling.

The NHBC 2019 standards under section 8 'Internal services' has a section 8.1.5 '*Hot Water Services'* and this details the expected flow rates of hot water services within the dwelling. Table 3 requires a design flow rate for non-electric showers of 12 litres/min with a minimum of 6 litres/min being achieved if multiple outlets are opened at once.

Whilst the WWG accepts that 12 litres/min in a time when we are looking to save energy seems excessive, there needs to be acknowledgment that this is a 33% increase of the minimum flow rate potentially installed/stated is installed to meet SAP requirements, but if NHBC receive a complaint regarding flow rate, this could quickly be altered with no single approach to updating the SAP assessment and highlighting that a property is now non-compliant.

Table 4 (Section 8.1.5) in the NHBC 2019Standards does actually allow a flow rate of 9 litres/min when there is only one shower room present (in line with original SAP 2009 flow rate) and we feel that this demonstrates a good base line for calculations considering a balance between their standards and achieving a level that occupants are willing to accept even though they might be lower than required.

Compliance

The WWG would like to understand how compliance will be monitored and checked for the actual installation of a flow restrictor/regulator? WWHRS like other SAP technologies requires certain conditions to be met during installation (Labels applied in the dwelling, documentation recording installation etc.), so that the EPC for the dwelling and future EPC's will be accurate.

From the specification of flow restrictor by the SAP assessor at design stage, how can it be monitored and checked across potentially 300,000 plus homes a year that a flow restrictor has been correctly installed to achieve the specified flow rate?

Finally, does BEIS/BRE have evidence of the life expectancy of flow regulator cartridges and maintenance regimes? Presumably the likelihood is that, if an installer or end user were to be required to remove the device for periodic cleaning that they will ultimately just remove it rather than repeatedly clean or replace.

Shower flowrate summary

The WWG is all for energy saving and CO_2 reduction and therefore we spend our time promoting the WWHRS technology. The group certainly sees the potential benefits in a drive towards reducing shower flow rates. However, this strategy alone seems to contain unknown elements that could actually lead to increased energy use and costs for occupants.

The limited number of subjects in the referenced research above shows that this area of research still needs further investigation, however, SAP 10 could potentially allow 300,000 homes per year to have DHW used when showering calculated at a lower value than any research so far has shown to be acceptable to a wider population.

Based on SAP Appendix Q definitions, it is difficult to see how the flow restrictor element can be used to calculate Energy use within Part L of the building regulations, without substantial evidence that occupants will be willing to use them, maintain them and replace like for like.

The regulations continue to increase fabric of the building and heating controls, without suggesting that homeowners should accept a reduction of internal temperature by 1,2 or 3 degrees which would affect user comfort. Yet, for hot water use in showering, the new proposals are suggesting that there will be a universal acceptance of shower flow rate reduction resulting in a change to current behaviour.

The WWG believe that there is substantial evidence to suggest that just reducing flow rate to the shower head, without considering the actual shower head being installed, the impact on shower experience and the potential repercussions for warranty providers like NHBC and their clients could have a negative rather than positive impact.

3. Shower Frequency and behaviour

Previous SAP calculations currently used a frequency of showering per occupant of 0.7x per day, giving an average of 5 showers per week per person.

Work by Artesia Consulting for South Staffordshire Water – '*WRMP19 Household consumption forecast: Baseline forecast*' (2017) predicts that the use of showering due to different reasons is increasing and will continue to increase towards 2030. The research seems to suggest a frequency of approx. 0.9x per day, resulting in an average of just over 6 showers per person per week.

As mentioned in section 1, the LJMU study reported a frequency of 0.87x per person and the WRc report 0.7x. The research by Artesia and LJMU already suggest that the number of showers being calculated in SAP per person could be an underestimation.

The new methodology being proposed in SAP 10 goes further to reducing this in the majority of new homes and varies depending on the number of occupants per house. The WWG has seen no evidence to suggest that an individual's habits will change depending on the number of other occupants within a dwelling. However, based on the equation: -

Nshower = 0.45 N + 0.65 (if any baths are present)

We are now in the position that if 2 occupants are calculated this would be approx. 0.775 showers per day per person (282.88 per year), like previous ratios. However, if 3 occupants were calculated this would drop to 0.67 showers per day per person (244.55 per year). Given the discussion in section 4 on occupancy and examination of the census data, the WWG believe that for 4+ bedroom homes the occupancy calculation should be moving towards 3.5 occupants and higher. With the current calculation this would mean 0.64 showers per day or lower per person (233.6 per year).

There were previous changes made to SAP 2012 when it was realised that the relationship between shower and bath ratio was causing an underestimation of shower usage. The WWG believe that this change to the shower usage calculation will lead to the same outcome.

Again, this needs to be considered moving towards 2030 in relation to peak demand loads as well as individual dwelling calculations. In a home with occupancy of 2.4, this is 175 extra showers (Frequency of 0.87 compared to 0.67) per year in each dwelling or nearly 52.5M extra showers across the new build sector (assuming the 300,000 new homes per year quoted by government).

Previous and current proposed SAP methodologies have all resulted in dwellings that have more than one shower, having all shower events evenly distributed between all showers. With larger homes normally having more showers and the current proposal on frequency resulting in less showers per occupant, this combined with an even split of hot water use (assuming same flow rates of showers) leads to dramatic reduction of the potential impact of WWHRS.

Considering even in these larger homes (the occupancy rate is currently calculating less than 3 occupants and given the data from the Census 2011) there is normally an en-suite within new homes, it is likely that 2 of these occupants will be using this as their main shower resulting in approx. 70% of showering attributed to one room. Current methodology means that a housebuilder will receive the same impact in SAP for a

WWHRS on a second en-suite used considerably less. This will impact on actual running costs and emissions of the dwelling.

Additionally, this calculation assumes that an occupant will make no behavioural change even if they know that certain showers in the dwelling will reduce costs by approx. 50%, yet it is assumed that it will be an accepted behavioural change to have a reduced shower flow rate.

The WWG strongly believe that there should be a weighting applied to showering frequency in dwellings with more than one shower to encourage installation on the most likely showers to be used and therefore have the desired impact of the technology being installed rather than just achieving SAP compliance.

4. Occupancy calculation

The current version of SAP (2012) and SAP 10 both appear to use the same occupancy rate calculation and on review, this appears to be used in the calculation of DHW, lighting, cooking and electrical appliances.

With the new fabric standards being introduced, DHW (depending on dwelling type) is shifting towards 35-50+% of the total energy demand of the home, so by far the occupancy rate calculation has the biggest effect on DHW over the users of energy.

The 2011 census for the first time reported number of bedrooms per dwelling and has allowed over and under crowding to be assessed across the country.

The WWG has a few observations from reviewing the data.

Looking at the person per bedroom across England and Wales (Attached is a 'Census 2011 - Number of occupants to bedrooms' excel sheet) it shows that 51% of the population are in a dwelling where there is over 0.5 and up to 1.0 person per bedroom, which based on the ratios available must either be:

- 2 Bedroom dwelling with 2 occupants
- 3 bedroom dwelling with 2 occupants
- 3 bedroom dwelling with 3 occupants
- 4 bedroom dwelling with 3 occupants
- 4 bedroom dwelling with 4 occupants
- 5 bedroom dwelling with 3 occupants
- 5 bedroom dwelling with 4 occupants
- 5 bedroom dwelling with 5 occupants

22% of the population are in a house where there are fewer bedrooms than number of occupants, which breaks down to: -

Over 1.0 and up to 1.5 persons per bedroom

- 2 Bedroom dwelling with 3 occupants
- 3 Bedroom dwelling with 4 occupants
- 4 Bedroom dwelling with 5 occupants
- 5 Bedroom dwelling with 6 occupants

Over 1.5 per bedroom

- 1 bedroom dwelling with 2 occupants
- 2 Bedroom dwelling with 4 occupants
- 3 Bedroom dwelling with 5 occupants
- 4 Bedroom dwelling with 6 occupants

From the information above, 13 out of the 16 scenarios require 3 or more occupants to be present in the dwelling and all scenarios with 3 or more bedrooms require 3 occupants or more.

A further request to the ONS provided data that can be found in the excel sheet '*England & Wales - Occupancy rates per bedrooms*'.xlsx. This sheet provides the break down of number of occupants found in dwellings with 1,2,3,4 and 5+ bedrooms. The information sent to the WWG was for England and Wales, with further analysis conducted on England & Wales combined and England alone. Additional lines added by the WWG can be seen in *italics*.

Based on the fact full SAP is designed for new build, the WWG feel that the inclusion of data for occupancy calculations using homes that come under the Tenure '*Owned outright*' should be eliminated or at least the impact on the calculation reduced as this proportion will be heavily influenced by existing houses and not those in new build.

The '*Summary*' tab on '*England & Wales - Occupancy rates per bedrooms'*.xlsx provides a comparison of average occupancy calculations between the Census information and SAP. As soon as a dwelling moves to 4 or more bedrooms the WWG believe the calculation is underestimating occupancy by approx. 0.5 - 0.9 persons. When looking at table 254 on the 'Live tables on house building: new build dwellings' web page, it shows consistency over the last 5 years that homes with 4+ bedrooms make nearly 40% of all house completions.

The current calculation in SAP requires a home to have a floor area of 200m^2 or higher for a dwelling to have an occupancy rate of 3 or more calculated.

'*The Technical housing standards – nationally described space standard*' – This document (Page 4; Table 1) gives the minimum gross internal floor areas required for different bedroom/person combinations. Whilst it is accepted by the WWG these are '*minimum*' standards, they do show that a 6 bedroom 8 person house designed over 3 floors only requires a space of 138m^2, which is 69% of the floor area required in SAP to predict 3 occupants and SAP would have the occupancy rate for DHW calculation of this property at 2.9 occupants.

Consultation Paper: CONSP:08 in section 1.1 concludes that the calculation for determining hot water required, normally yielding 80 to 110 litres per day, is based on robust data from '*Measurement of Domestic Hot Water Consumption in Dwellings*' prepared by Chris Martin, Energy Monitoring Company for the Energy Saving Trust. March 2008. given that average occupancy is between 2-3 in the majority of cases.

However, the paper by Chris Martin clearly indicates that the 'Regular' boilers in this work were mainly gravity fed systems (Section 6.3.3; Page 17). The average use in dwellings with a combi boiler was 142 $\pm$ 28 litres per day, and with all new homes fitted with a regular boiler having an unvented cylinder, it is known that these tend to supply a higher flow rate of water on mains pressure to outlets compared to a combi boiler.

Therefore, as an assumption that an unvented cylinder if measured would produce a hot water usage of 156 litres per day (10% increase on the combi boiler), this would give an average of 149 litres per day per household (combi homes + unvented cylinder homes). Using the calculation used in SAP 2012 ($V_{d,average}$ = (25* N) + 36), would result in occupancy being calculated at 4.5 on average, even based on the combi average this results in an average of 4.24 occupants per dwelling.

Therefore, if occupancy rate calculation is deemed to be correct then the average level of DHW used per person should be reviewed.

Occupancy calculation summary

Considering that new build dwellings modelled to the proposed new standards are showing energy for DHW moving towards a similar level as that of space heating, the use of the WWG believe the current occupancy calculation to determine hot water use needs to be reviewed.

Given the data from the census in 2011, the WWG believe that a ratio-based system between the number of bedrooms and anticipated occupancy should be considered in order to stop under estimation of DHW use in house types with 3+ bedrooms. Potential variations for the ratio should be considered based on dwelling type (House/Flat) and type of tenure (Private sale or social) especially with affordability becoming a key criterion.

The underestimation of occupation **and** of DHW use per person (based on data over 10 years old) within new build dwellings could have large and long-lasting impacts on the 2030/2050 targets that the government have set.

Between 2020-2050 based on the government targets, this would see 9 million new homes built (nearly 40% of the total number of households in the 2011 census). At the same time the country will be transitioning to zero carbon energy production and the extra load at peak times would be considerably more than the notional dwellings will be calculating.

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5. Hot water standards

Requirements of L1a and L1b in the consultation draft provide details of minimum excepted standards for hot water in with respect to heat losses (pipe work and stored hot water), time and temperature controls.

In regard to L1a, section 4.16 provides details on the maximum accepted heat losses from cylinders in order to provide limited heat losses. An average cylinder size for a 3-5 bedroom house is between 150-250 litres. Table 4.3 gives heat losses for this range of 1.88-2.22 kWh/24h.

Based on 6 minutes and 8 litres/min as the minimum energy used for showering per occupant, this works out to 1.5 kWh of energy per shower with approx. 1.23 kWh still in the waste shower water as it leaves the building. If occupancy is calculated at 2.3 this is 2.83 kWh of energy for all occupants showering and based on an average shower frequency of 0.8x per day would be 2.26 kWh per 24 hours which is higher than the cylinder minimum standard. Given that for the cylinders, this heat loss in certain months of the year would be actually contributing to the heating of the actual dwelling (potentially 6 months of the year) there is twice as much energy being lost through the waste pipework as there is from a cylinder.

If we consider 7.5 minutes per shower (as per EST research) and 11 litres/min (standard in SAP if no adjustment made) this increases to 2.6 kWh per shower with 2.13 kWh being lost from the building through the waste pipes. For 2.3 occupants this is 3.92 kWh per day.

Potentially 4x as much energy is lost from the building via the waste pipe (waste pipes could be considered as part of the buildings fabric) as is lost from a cylinder (assuming 6 months is contributing to the dwellings heating) over a 24-hour period.

The requirements under L1a and L1b for heating are still being increased (and rightly so) to keep minimising energy use and are obviously backed up by the increasing fabric requirements of the dwelling. However, despite hot water now requiring a similar level of energy per dwelling, the hot water standards do not appear to have this ‘fabric’ back up to support the minimum standards to limit the heat losses from the building in regard to hot water.

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