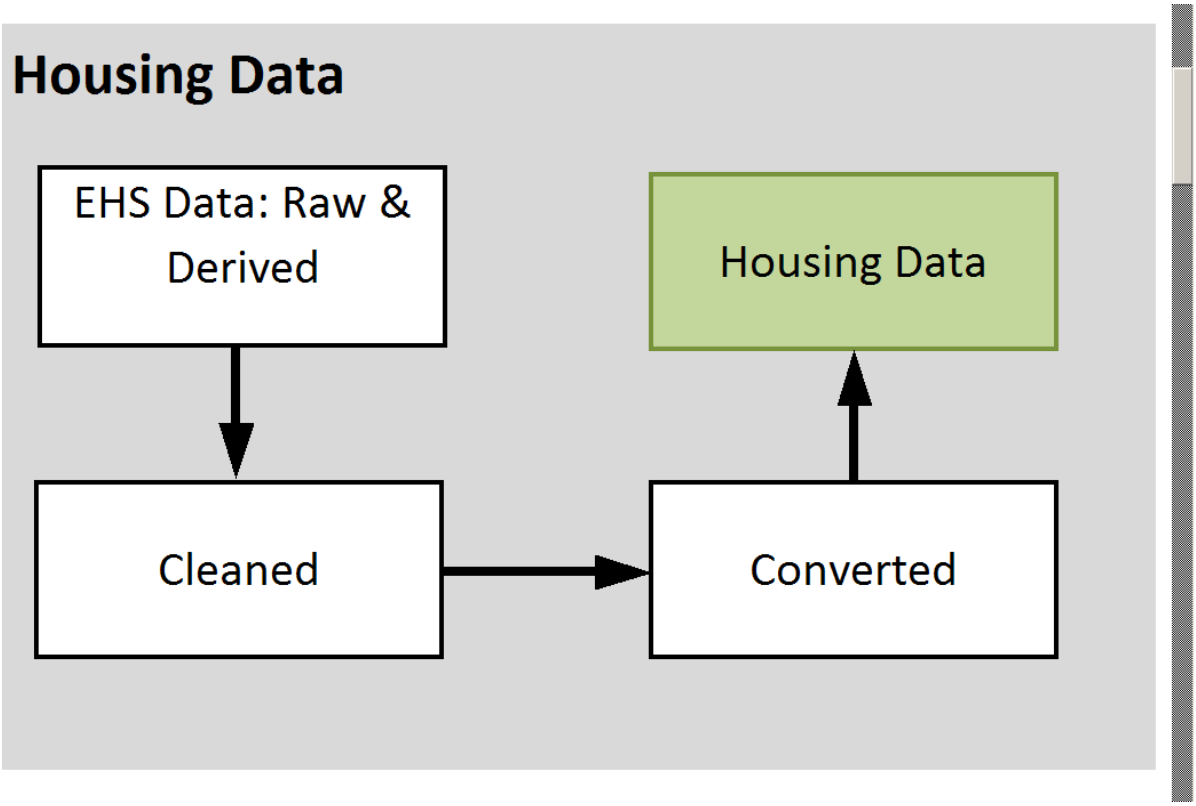
Converting English Housing Survey Data for Use in Energy Models



January 2012

Cambridge Architectural Research

University College London

Converting English Housing Survey Data for Use in Energy Models

Introduction

Before data from the English Housing Survey can be used in a SAP-based model like the Cambridge Housing Model (CHM), it has to be both cleaned and converted to align it with the inputs needed for SAP. A sequence of conversions is needed, and this document summarises an approach to such conversions.

This document is necessarily detailed and technical. It will interest readers who have themselves worked with the EHS to do stock modelling work. Other people may be more interested in the outcomes of this modelling work, including Energy Consumption in the UK (see Domestic data tables).

This work is a collaborative endeavour, written by Martin Hughes, Peter Armitage and Jason Palmer at CAR, and Andrew Stone at UCL. Special thanks are due to Andrew for his work on boiler identification. We intend to refine the document over time, and any comments or suggestions for improvements are welcome – please direct suggestions to ehsmodel@carltd.com.

The Conversion Process

This section goes through the input data needed for a SAP-based model, and describes the conversion process used to generate them. The datasets are considered in appropriate groupings:

1. Dwelling and Household Information
2. Geometry
3. Ventilation
4. Other Heat Loss Elements
5. Space Heating
6. Hot Water System
7. Low Energy Lighting

1. Dwelling and Household Information

The following data is read directly from the EHS dataset, and is not converted[1]:

- Derived\general\aacode: V001 - Housing code
- Derived\general\aagpd78: V002 - Dwelling weight
- Derived\general\gorEHCS: V008 - Government office region

This gives us:

- **H001: Housing Code** (V001_HousingCode)
- **H002: Number of Dwelling** (V002_DwellingWeight)
- **H008: Region** (D003_Region)

The following EHS data is not in the exact format required by the CHM:

- Raw Physical\Firstimp\fodconst: V003 - Construction date
- Derived\general\tenure8x: V004 – Tenure
- Derived\physical\dwtype7x: V005 - Dwelling type

We therefore map from the EHS data to equivalent CHM datasets using conversion tables. The 8 EHS tenure types are easily mapped to 4 SAP tenure types:

1. Private owner occupied
2. Local authority / other public
3. Housing association / co-operative
4. Private rented

Whilst the dwelling type mapping actually just involves a re-numbering to align with the SAP definitions; the categories themselves are the same. This gives us:

- **H004: Tenure Type** (D004_Tenure)
- **H005: Dwelling Type** (D002_DwellingType)

[1] EHS datasets (denoted by references starting with V) are listed as bullet points (●). These datasets are listed as they have been used in the conversion process for the CHM, however we only list them once. The conversion process is then described in text; the output, a "Housing Data" dataset, is listed as a dashed bullet point (-), has a reference starting with H, and is represented here in **bold blue** type. Individual input datasets (V) and output datasets (H) may be used multiple times elsewhere in the conversion process; if so they are referenced in any text description but are not re-listed.

For the age band mapping several of the EHS age bands map onto 2 different SAP age bands, for example EHS age band 4 covers the period 1919 to 1944 inclusive, whilst the SAP age bands 2 and 3 cover the periods 1900 to 1929 and 1930 to 1949 inclusive, respectively:

EHS Band	EHS Period	SAP Band	SAP Period
1	pre 1850	1	Before 1900
2	1850 – 1899	2	1900 – 1929
3	1900 – 1918	3	1930 – 1949
4	1919 – 1944	4	1950 – 1966
5	1945 – 1964	5	1967 – 1975
6	1965 – 1974	6	1976 – 1982
7	1975 – 1980	7	1983 - 1990
8	1981 - 1990	8	1991 – 1995
9	1991 - 1995	9	1996 – 2002
10	1996 - 2002	10	2003 - 2006
11	Post 2002		

Table 1: EHS and SAP age bands

SAP age bands are used both in the Conversion process and within the CHM to lookup values in SAP tables. To identify the appropriate values from such tables, in instances where the known EHS band relates to two SAP age bands, the proportion of the EHS age band that lies within each of the corresponding two SAP age bands is determined.

This is based on the number of years in an individual EHS age band that falls into each of the two SAP age bands:

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1.00									
2	1.00									
3		1.00								
4		0.4231	0.5796							
5			0.25	0.75						
6				0.2	0.8					
7					0.1667	0.8333				
8						0.2	0.8			
9								1.00		
10									1.00	
11										1.00

Table 2: Proportional mapping from a single EHS age band to two SAP age bands, where appropriate. SAP age bands are represented in columns and EHS age bands in rows.

Values from the SAP tables corresponding to both SAP age bands are identified, and a new value is calculated proportionally based on the two SAP values and the proportions of the SAP age bands relating to the single EHS age band. For example, for a representative dwelling with EHS age band 4, and appropriate values from a SAP table of 1.0 for SAP age band 2 and 2.0 for SAP age band 3, the used value is calculated as (0.4231 x 1.0) + (0.5796 x 2.0).

A similar approach is used in the CHM, so it is necessary to use the EHS age band and the same mapping approach within the CHM. This gives us:

- **H003: SAP Age band** (D001_DwellingAge)
- **H116: EHS Age band** (V003_ConstructionDate)

The EHS provides data on the total number of dwelling occupants and the number of children:

- Derived\interview\hhsizex: V006 – Number of persons in household
- Derived\interview\NDEPCHILD: V007 – Number of dependent children in household

This information is combined to give:

- **H006: Occupant – Adult** (D007_OccupantsAdult)
- **H007: Occupant – Children** (D006_OccupantsChildren)

2. Geometry

The geometry calculations form a considerable part of the conversion process, and large amounts of EHS data is used for these geometry calculations.

- Derived\dimensions\FloorArea: V009 – Total floor area (m^2)
- Derived\physical\storeyx: V010 – Number of floors above ground
- Raw Physical\Flatdets\fdffloor: V118 – Number of floors in flat
- Raw Physical\Interior\finlivcl: Four datasets V033, V034, V035 & V036: Ceiling height – living room, Ceiling height – kitchen, Ceiling height – bedroom and Ceiling height – bathroom.

The average of the ceiling height values is taken (excluding zeros) to determine an average ceiling height. To calculate storey height 0.25m is added to this average ceiling height, except for the lowest storey of the dwelling – as per SAP 2005 RdSAP S3.3. The following "Housing Data" datasets are so generated:

- **H010: Basement Storey Height** (D041_BasementHeight)
- **H012: GF Storey Height** (D042_GroundFloorHeight)
- **H014: 1F Storey Height** (D043_1stFloorHeight)
- **H016: 2F Storey Height** (D044_2ndFloorHeight)
- **H018: 3F Storey Height** (D045_3rdFloorHeight)

- Derived\physical\attic: V011 – Attic present in dwelling

This is used to determine whether there is a "room in roof". If so the room in roof ceiling height is determined to be a default value (currently 2.45m) based on SAP 2005 RdSAP S3.6. This gives:

- **H020: Room in roof Storey Height** (D046_RoomInRoofHeight)

- Raw Physical\Shape\fdhmlev1: V013 – Module – main structure level 1
- Raw Physical\Shape\fdhmwid1: V014 – Module – main structure width 1
- Raw Physical\Shape\fdhmdep1: V015 – Module – main structure depth 1
- Raw Physicall\Shape\fdhalev1: V016 – Module – additional part level 1
- Raw Physical\Shape\fdhawid1: V017 – Module – additional part width 1
- Raw Physical\Shape\fdhadep1: V018 – Module – additional part depth 1
- Raw Physical\Flatdets\fdfsamed: V028 – Flat – external dimensions provided in EHCS
- Raw Physical\Shape\fdhmlev2: V029 – Module – main structure level 2
- Raw Physical\Shape\fdhmlev3: V030 – Module – main structure level 3
- Raw Physical\Flatdets\fdfmainl: V031 – Flat – main floor level

- Raw Physical\Flatdets\fdfnextl: V032 – Flat – next floor level
- Raw Physical\Shape\fdhmwid2V048- Module – main structure width 2
- Raw Physical\Shape\fdhmdep2: V049 – Module – main structure depth 2
- Raw Physical\Shape\fdhmwid3: V050 – Module – main structure width 3
- Raw Physical\Shape\fdhmdep3: V051 – Module – main structure depth 3
- Raw Physical\Shape\fdhalev2: V052 – Module – additional part level 2
- Raw Physical\Shape\fdhawid2: V053 – Module – additional part width 2
- Raw Physical\Shape\fdhadep2: V054 – Module – additional part depth 2
- Raw Physical\Shape\fdhalev3: V055 – Module – additional part level 3
- Raw Physical\Shape\fdhawid3: V056 – Module – additional part width 3
- Raw Physical\Shape\fdhadep3: V057 – Module – additional part depth 3
- Raw Physical\Flatdets\fdfmainw: V058 – Flat – main floor width
- Raw Physical \Flatdets\fdfmaind: V059 – Flat – main floor depth
- Raw Physical \Flatdets\fdfnextw: V060 – Flat – next floor width
- Raw Physical \Flatdets\fdfnextd: V061 – Flat – next floor depth
- Raw Physical\Services\finlopos: V062 – Flat – position
- Raw Physical \Flatdets\fdffloor: V118- Number of floors in flat

Total Floor Area (TFA) (V009) has been determined in the EHS derived physical dataset, therefore we take this to be definitive.. The dimensions of up to three levels in houses are defined by the width and depth of the main structure (e.g. V014, V015) and an additional module (e.g. V017,V018) and room in roof if applicable. In flats, the width and depth of up to two levels are given (V058 – V061).

However in many cases the physical dimensions of the modules (width W and depth D) need to be adjusted to ensure consistency with the TFA. A Linear Scaling Factor (LSF) is used to calculate “pseudo” dimensions W’ and D’ for each area, as follows:

$$LSF = \sqrt{\frac{TFA}{\sum(W * D)}}$$

$$W' = LSF * W \qquad D' = LSF * D$$

The “pseudo” dimensions are used to calculate a “pseudo” area for each floor, which is consistent with both the proportions of the physical dimensions, and the derived TFA.

If the dwelling is a house then Module 1 must relate to either the basement or the ground floor; V013 specifies whether Module 1 relates to a basement or not, therefore the allocation is made based on this. Module 2 & 3 data is then allocated to higher floors following on from the allocation of Module 1. In the CHM we specify only the following floors: a basement, a ground floor, a 1^{st} floor, a 2^{nd} floor, "higher" floors and a "room in roof "; V010, the number of floors above ground is used to determine which floors are present. If there is a 2^{nd} floor we may or may not explicitly have dimensional data for this floor – depending on whether or not the Module 1 data relates to a basement or not; if there is no basement then the Module 3 data relates to the 2^{nd} floor, however if there is a basement the Module 3 data relates to the 1^{st} floor; nevertheless we assume that the 2^{nd} floor has the same dimensions as the floor below it, therefore effectively the 2^{nd} floor dimensions always relate to Module 3. "Higher floors" relate to floors above the 2^{nd} but excluding any room in roof; the area of any higher floors are assumed to be the same as the 2^{nd} floor.

V010 minus 3 (ground, 1^{st} & 2^{nd}) tells us how many floors there are above the 2^{nd} floor; the dataset "Attic present in dwelling" (V011), tells us whether there is a room in roof; the number of higher floors is then taken as V010 minus 3 and minus a further 1 if there is a room in roof; the area of any room in roof is taken as half that of the next highest floor. Based on these assumptions the presence or absence of each floor can be determined and the pseudo areas can be determined for each floor; in the case of "higher floors" the number of higher floors can also be determined and pseudo areas calculated appropriately. In this way the TFA for the dwelling is retained as the derived input value V009, but this area is apportioned according to the number of floors in the dwelling and the modular width & depth dimensions.

If the dwelling is a flat a similar approach is taken, with a few variations. It is assumed that there is no room-in-roof in a flat (V011 relates to houses only). "Flat – external dimensions provided in EHCS" (V028) identifies whether the modular data corresponds to the dimensions of the dwelling (for a flat the modular data could relate to the dimensions of any "block" that the dwelling is a part of); if the two sets of dimensions are consistent then the modular data is used (as for a house), however if they are inconsistent the "flat –main floor level" (V031), "flat – next floor level" (V032), and associated dimensional data V058 – V061 is used; note that there is only data on two levels here. Although we can generate pseudo areas based on the above information, the determination of which floors are present in a flat differs from a house; whereas we assume all houses have a ground floor and can incrementally step from a basement to a ground floor to a 1^{st} floor etc., in a flat the lowest level of the dwelling could start anywhere in a "block" of flats; we therefore use "Flat – position" (V062) and "Number of floors in flat" (V118) to identify the floors in a flat. If either the flat is a basement flat (V062) or V013 specifies that Module 1 relates to a basement, then a basement floor is assumed, otherwise not; if either the flat is a ground floor flat (V062) or V013 specifies that either Modules 1 or 2 relate to a ground floor, then a ground floor is assumed, otherwise not; the presence or otherwise of any further floors (1^{st}, 2^{nd} or "higher") is determined based on the number of floors in the dwelling (V118) and the presence or absence of lower floors; the quantity of any "higher" floors can also be determined from this information. Note that for a flat there are three features of prime interest: whether the flat has a ground floor or basement (which impacts on the value of any basement floor or ground floor heat loss areas); whether the flat is "top floor" (which impacts on the value of the roof heat loss area); and how may floors the TFA must be apportioned over. Because of this we can apportion floors to 1^{st}, 2^{nd} or "higher" floors even if this is not strictly correct (e.g. the flat could be on the 18th floor but for our purposes it doesn't matter whether we specify the floor as the 1st or the 18th, as long as we correctly account for the basement/ground floor, top floor & number of floors). Based on this identification of floors and the associated determination of dimensions, pseudo areas can be calculated for each floor.

All of these calculations enable us to determine:

- **H009: Basement Area** (D035_BasementArea)
- **H011: GF Area** (D036_GroundFloorArea)
- **H013: 1F Floor Area** (D037_1stFloorArea)
- **H015: 2F Floor Area** (D038_2ndFloorArea)
- **H017: 3F Floor Area** (D039_3rdFloorArea)
- **H019: Room in roof Area** (D040_RoomInRoofArea); *note this is the room-in-roof floor area.*

The basement floor heat loss area is assumed to be the same as the basement floor area, giving:

- **H053: Basement Floor Heat Loss Area** (D059_BasementFloorHeatLossArea)

In addition, if H011 is less than H009 then the ground floor heat loss area is assumed to be zero, otherwise the ground floor heat loss area is taken as H011 minus H009, giving us:

- **H056: GF Heat Loss Area** (D060_GroundFloorHeatLossArea)

If the dwelling type (H005) is not a flat then the roof area is taken as the maximum area out of all of the floor areas, minus any room in roof *floor* area (H019); if this is a flat but not a top floor flat (V062) then the roof area is assumed zero; if this is a top floor flat the roof area is assumed to be the same as the floor area for the highest floor present in the dwelling. This gives us:

- **H069: Roof Area** (D061_RoofArea)

If the dwelling is anything other than a top floor or mid floor flat (V062) then the party floor area is assumed to be zero; otherwise the party floor area is assumed to be the same as the ground floor area (H011) if this is greater than zero, otherwise it is the same as the 1st floor area (H013). This gives:

- **H075: Party Floor Area** (D062_PartyFloorArea)

If the dwelling is anything other than a ground floor or mid floor flat (V062) then the party ceiling area is assumed to be zero; otherwise the party ceiling area is assumed to be the same as the floor area for the highest floor present in the dwelling. This gives us:

- **H077: Party Ceiling Area** (D063_PartyCeilingArea)

- Raw Physical\Interior\finrooms: V041 – Habitable rooms number
- Raw Physical\Interior\finlivwi: V128 – Living room width
- Raw Physical\Interior\finlivde: V129 – Living room depth

Calculate living area fraction = living room area/total floor area (V009), where living room area is calculated by multiplying living room width by depth (V128 by V129). If living room area = 0 due to unknown width/depth values, use RdSAP value based on room count: cross-reference the number of habitable rooms (V041) against the Living area fraction RdSAP SAP 2005 Table S16. In this way the following is determined:

- **H060: Living Area Fraction** (D078_LivingAreaFraction)

- Derived\physical\typewstr: V019 – Predominant type of wall structure
- Raw Physical\Elevate\felcavff: V119 – Cavity wall insulation – front
- Raw Physical\Elevate\felcavlf: V120 – Cavity wall insulation – left
- Raw Physical\Elevate\felcavrf: V121 – Cavity wall insulation – right
- Raw Physical\Elevate\felcavbf: V122 – Cavity wall insulation – back
- Raw Physical\Elevate\felextff: V020 – Wall external insulation – front
- Raw Physical\Elevate\felextlf: V021 – Wall external insulation – left
- Raw Physical\Elevate\felextrf: V022 – Wall external insulation – right
- Raw Physical\Elevate\felextbf: V023 – Wall external insulation – back
- Raw Physical\Firstimp\fodconst: V003 – Construction date

The external wall thickness (D030_WallThickness) is calculated as follows: Use V019 to determine the predominant wall type; use V119-V122 to determine whether the dwelling has cavity wall insulation; use V020-V023 to determine whether the dwelling has external wall insulation. Combining the information on the predominant wall type with the information on the presence or absence of wall insulation enables us to allocate the wall type to one of the categories outlined in RdSAP 2009. In this way "D029_WallConstruction" is determined. Finally this wall type is cross-reference against the dwelling age (V003) using the RdSAP SAP 2005 Table S3 Table "Wall thickness (m)" to determine wall thickness. Table S3 uses the SAP age band as a reference; this is one of the instances where we use the "AgeMapTable", relating the EHS age band to 2 SAP age bands if appropriate, in order to calculate wall thickness more appropriately. This calculation of D029 provides:

- **H061: Basement Wall Construction** (D076_BasementWallConstruction)
- **H063: External Wall Construction** (D077_ExternalWallConstruction)
- **H065: Semi-exposed Wall Construction** (D122_SemiExposedConstruction)[2]
- **H117: Wall Thickness** (D030_WallThickness)

Note that at this time the presence or absence of cavity wall insulation and external wall insulation is determined as follows: The number of walls with external insulation is determined from V020 to V023; a dwelling is assumed to have external wall insulation if the number of walls with external insulation is greater than or equal to the number of external walls. A dwelling is assumed to have cavity wall insulation if ANY of the external walls have cavity wall insulation, from V119 to V122.

- Raw Physical \ Elevate\ fvwtenff: V146 – Tenths of elevation attached – front
- Raw Physical \ Elevate\ fvwtenbf: V147 – Tenths of elevation attached – back

[2] In the absence of specific information on the construction of semi-exposed walls, they are assumed to have the same construction as the External Walls (D029_WallConstruction).

- Raw Physical \ Elevate\ fvwtenlf: V148 – Tenths of elevation attached – left
- Raw Physical \ Elevate\ fvwtenrf: V149 – Tenths of elevation attached – right

For both houses and flats, the number of sheltered sides is related directly to the number of attached/unattached sides (V146-V149). A side is considered sheltered if it is more than 50% (five tenths) attached. The total number of sheltered sides (an integer value from 0 to 4) is summed. This gives us:

   - **H034: Sides sheltered** (D056_SidesSheltered)

Perimeter Calculations, including Additional Modules:

- Raw Physical \Shape\fshaddit: V133 – Location of additional module

Where an additional module is included, the geometry of the building is modified to reflect this. Fshaddit gives the location of the additional module in relation to the main structure of the building, as shown in the table below:

Additional Module Location			
Front elevation: Left	1	Left elevation: Centre	8
Front elevation: Centre	2	Left elevation: Back	9
Front elevation: Right	3	Right elevation: Front	10
Back elevation: Left	4	Right elevation: Centre	11
Back elevation: Centre	5	Right elevation: Back	12
Back elevation: Right	6	No additional part	77
Left elevation: Front	7	Unknown	99

Table 3: Location of Additional Module (fshaddit)

The resulting geometry for each of the different fshaddit cases is shown in the figure over page.

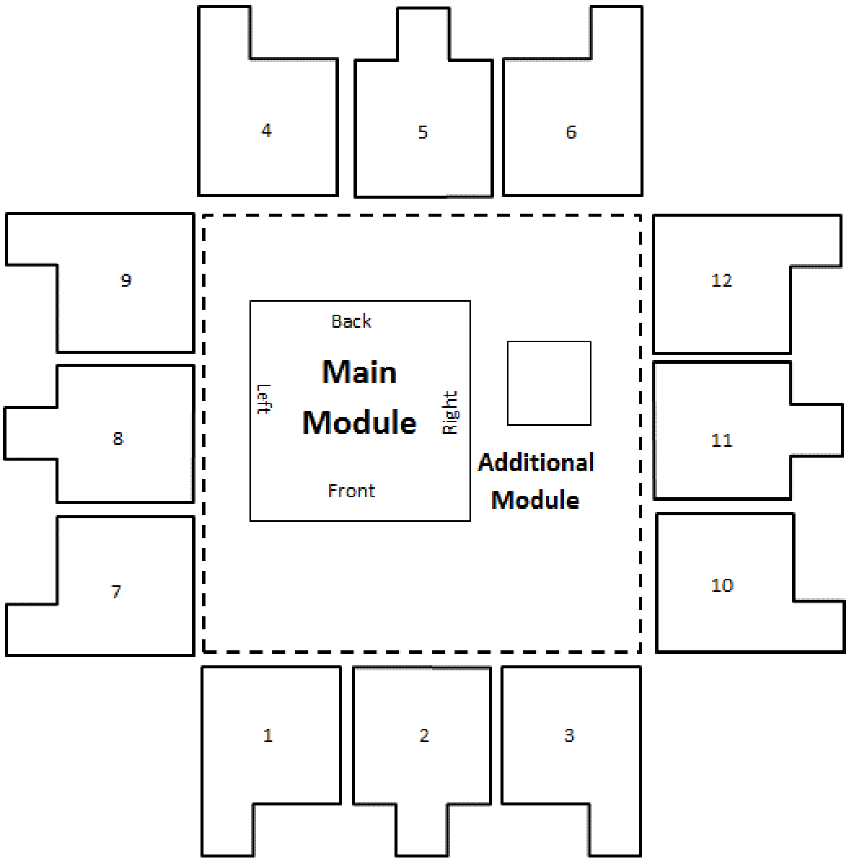


Figure 1: Location of Additional Module (fshaddit)

The perimeter and hence the façade dimensions of the resulting geometry can then be calculated for each of the elevations (front, back, left, right), according to the following diagram:

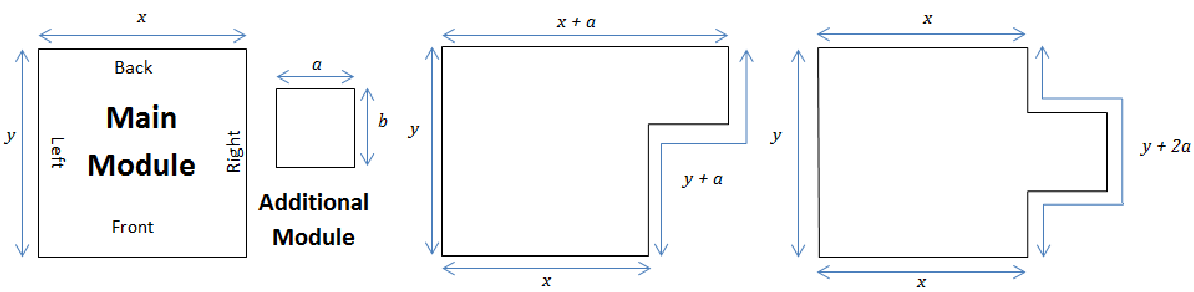


Figure 2: New dimensions following the attachment of an additional module

Façade Calculations:

- Raw Physical\Doors\fexdf1: V042 – Door number – wood_front
- Raw Physical\Doors\fexdf1:V044 – Door number – UPVC_front
- Raw Physical\Doors\fexdf1:V046 – Door number – metal_front
- Raw Physical\Doors\fexdf2: V043 – Door number – wood_back
- Raw Physical\Doors\fexdf2: V045 – Door number – UPVC_back
- Raw Physical\Doors\fexdf2: V047 – Door number – metal_back

- Raw Physical \Flatdets\fdffrooa: V123: Tenths of wall exposed to outside air – front
- Raw Physical \Flatdets\ fdflftoa: V124 – Tenths of wall exposed to outside air – left
- Raw Physical \Flatdets\ fdfrigoa: V125 – Tenths of wall exposed to outside air – right
- Raw Physical \Flatdets\ fdfbckoa: V126 – Tenths of wall exposed to outside air – back
- Raw Physical \ Elevate\ felfenfw: V134 – Tenths of elevation windows – front
- Raw Physical \ Elevate\ felfenbw: V135 – Tenths of elevation windows – back
- Raw Physical \ Elevate\ felfenlw: V136 – Tenths of elevation windows – left
- Raw Physical \ Elevate\ felfenrw: V137 – Tenths of elevation windows – right
- Raw Physical \ Flatdets\ fdffroia: V150 – Tenths of wall exposed to internal access – front
- Raw Physical \ Flatdets\ fdfbckia: V151 – Tenths of wall exposed to internal access - back
- Raw Physical \ Flatdets\ fdflftia: V152 – Tenths of wall exposed to internal access - left
- Raw Physical \ Flatdets\ fdfrigia: V153 – Tenths of wall exposed to internal access - right
- Raw Physical \ Flatdets\ fdffroof: V154 – Tenths of wall exposed to other flats - front
- Raw Physical \ Flatdets\ fdfbckof: V155 – Tenths of wall exposed to other flats - back
- Raw Physical \ Flatdets\ fdflftof: V156 – Tenths of wall exposed to other flats – left
- Raw Physical \ Flatdets\ fdfrigof: V157 – Tenths of wall exposed to other flats – right

The Total Façade area for each elevation may be calculated using the perimeter dimensions of the main and additional modules, multiplying by the storey height for each floor. The total façade area is then divided into the party walls, windows and doors, external façade and semi-exposed walls, using the data on the attached tenths of walls (V146-V149), doors (V042-V047) and the glazed tenths of walls (V134-V137). In flats, the tenths of walls exposed to internal areas and to other flats (V150-V157) are also used.

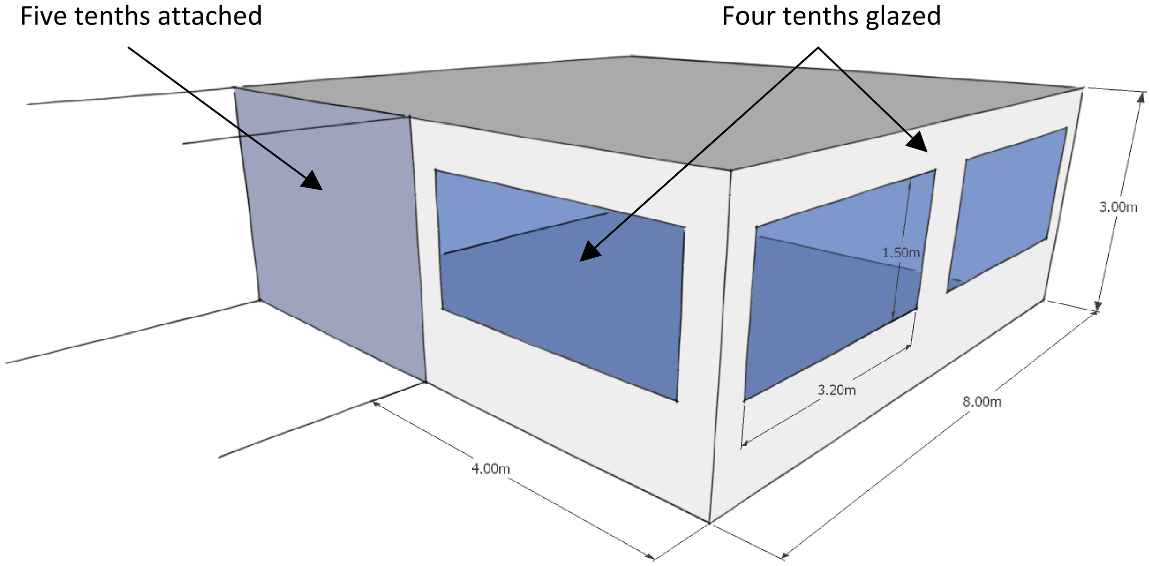


Figure 3: Illustration of two facades, both with four tenths glazing, where one façade also has five tenths attached wall.

Attached Façade Area

The first step in calculating the façade areas is to use the attached tenths data to find the area of each façade that is attached. The other tenths data, describing the external walls, glazing and voids, is assumed to refer to tenths of unattached façade, so that it is possible for two façades to have six tenths glazing, even though one wall is five tenths attached (see Figure 3).

Party Wall Area: In houses, the area of attached facades is assumed to be the area of party walls. In flats, the attached walls are calculated based on the tenths of walls that are exposed to other flats (V154-V157). These measures are used to calculate:

- **H073: Party Wall Area** (D073_PartyWallArea)

In houses, if a Room in Roof is present it is assumed that there all facades on this level are unattached.

Unattached Façade Area

The Unattached Façade Area is calculated by simply subtracting the Attached Façade area from the Total Façade area for each elevation. The Unattached Façade is made up of the external walls, semi exposed walls and openings, which includes both doors and glazed areas (referred to here as 'glazed tenths', reflecting the EHS survey form). Due to some inconsistencies found between the different facade data sets, it was assumed that the glazing tenths were definitive when calculating the makeup of unattached facades, and is calculated first.

Window and Door Areas: The glazed tenths data for each elevation is used to find the area of unattached façade that is taken by openings, such as doors or windows. Firstly, a total Opening Area is found by multiplying the Unattached Façade Area by the glazed tenths for each elevation (V134-V137).

Following this, the total door area is calculated. This uses the six datasets on the presence and type of external doors (V042-V047) to give a total number of doors, which is then multiplied by a default single door area value (1.85m^2, taken from SAP 2005 RdSAP S3.4),giving a preliminary total door area. However due to apparent inconsistencies in the data (e.g. 14 doors in a mid-terrace dwelling), this area is compared to the total opening area given by the glazed tenths. If the number of doors implies a greater area than the total Opening Area, the preliminary total door area is limited to the Opening Area (i.e. doors make up the total Opening Area). This gives:

- **H036: Door Area** (D057_DoorArea)

The Window Area is then found by subtracting the Door Area from the Openings Area for each elevation. Finally, the Window Area is apportioned between the 2 possible window types: single or double glazed. We use the following data:

- Derived\physical\dblglaz2: V075 – Double glazing extent 1
- Derived\physical\dblglaz4: V076 – Double glazing extent 2

An assessment of these two datasets expressing the extent of double glazing in each dwelling, V075 & V076, allows us to determine the proportion of single (Windows 1 Type), and double (Windows 2 Type) glazing. These proportions can then be applied to the total window area determined above, giving:

- **H039: Windows 1 Area** (D067_Windows1Area)
- **H044: Windows 2 Area** (D069_Windows2Area)

External Wall Area: The external wall areas are calculated by subtracting the total Opening Area from the Unattached Area. Exposed wall areas are considered in terms of the exposed basement wall area and the exposed external wall area, the latter relating to all exposed wall areas above ground. The window and door areas are subtracted from both the basement and external walls areas, proportionally; the proportions are according to the ratio of exposed wall area in the basement and exposed wall area above ground. This gives us:

- **H064: External Wall Area** (D065_ExternalWallArea)
- **H062: Basement Wall Area** (D064_BasementWallArea)

It is recalled that for the calculation of H069 Roof Area, we subtracted the area of any room-in-roof *floor* area. We are now in a position to calculate the heat loss area for any room-in-roof, as the sum of the wall areas (calculated based on the façade calculations above) plus the room-in-roof *floor* area H019. Note, however, that in the rare circumstances where a dwelling ONLY consists of a room-in-roof, the room-in-roof area must therefore have the total window and door areas subtracted from its external area, in order to give the correct total exposed area. In this way we determine:

- **H071: Roof – room in roof Area** (D066_RoomInRoofHeatLossArea)

We further need to determine the basement and ground floor exposed perimeters. Having already identified the external wall areas for both the basement and the ground floor, and the heights of each of these storeys, we can simply calculate the exposed perimeter by dividing the total basement or ground floor external wall areas by their respective storey heights. (Note that there is an assumption here that for flats, walls which are not external but are attached to “communal” areas such as stairwells, are NOT considered to be unattached and therefore we are effectively assuming that they are heated and not counted as part of an exposed perimeter.) This gives us:

- **H054: Basement Floor Exposed Perimeter** (D113_BasementFloorExposedPerimeter)
- **H057: GF Exposed Perimeter** (D114_GroundFloorExposedPerimeter)

Semi-Exposed Wall Area: Semi exposed walls are only included in flats, and correspond to walls that facing on to internal accessways (V150-V153). This gives

- **H066: Semi-exposed Wall Area** (D121_SemiExposedArea)

3. Ventilation

Quantities of chimneys come from four EHS datasets:

- Raw Physical\Chimney\fexcs1no: V037 – Chimney number – type 1_front and V039 – Chimney number – type 2_front
- Raw Physical\Chimney\fexcs2no: V038 – Chimney number – type 1_back and V040 – Chimney number – type 2_back
- Raw Physical\Services\Finohage: V130 – Age of Other Heating

The quantities in V037-V040 inclusive are totalled to give a total for the number of chimneys. However two issues now arise: (i) whether the chimneys are blocked, and (ii) whether, because of any secondary heating present any chimney needs to be thought of as a flue as opposed to a chimney. Both of these issues impact on the ventilation calculations, and the issue here is really how the counted number of chimneys stacks should be interpreted from a ventilation viewpoint. Therefore we have made some further calculations. If there is more than 1 chimney then we re-set the figure to be 1. If there is a secondary heating system, and from H114 Secondary Heating System below, the system is identified as a gas fire, and if this system has been introduced since 1975, as determined from V130 the age of any other heating system, and if there is a chimney then in fact this is now assumed to be a flue. That is the number of secondary heating open flues is increased by one and the chimney count becomes zero. This gives:

- **H021: Chimneys – Main heating** (D047_ChimneyNumber)

The quantities of the other two types of chimney required as input to the CHM are then assumed to be zero (it is only the total number of chimneys that is of interest):

- **H022: Chimneys – Secondary heating** (H022_Chimenys_SecondaryHeating)
- **H023: Chimneys – Other** (H023_Chimneys_Other)

Data on the main heating system is assessed to determine whether it incorporates an open flue:

- Raw Physical\Services\finchbcd: V085 – Primary heating appliance code
- Raw Physical\Services\finmhboi: V086 – Primary heating boiler type
- Raw Physical\Services\ Finchbma: V131 – Primary heating boiler brand
- Raw Physical\Services\ Finchbmo: V132 – Primary heating boiler model

The EHS heating system information specified in V085, V086, V131 and V132 is used to determine details of the heating system. This is described in detail in Section 5, “Space Heating”, below. In the first instance, if the EHS information can be associated with a specific system whose details can be identified in a Product Characteristics Database, then any associated information that we require such as the nature of any flue, any heat emitters and the efficiency of the system, can be determined directly from that database. However, if the heating system cannot be identified exactly then an alternative approach must be used, both to determine the system type and any associated features. V085 specifies the system as one of a series of high level systems based on the 2007 EHCS Surveyor Briefing Manual Part 1 (p.91). These are listed in the table below, numbered 101, 102, etc.

EHCS primary heating code / system		Heating system	Boiler flue	Heat emitter	System efficiency
101	Gas – fan assisted, electric ignition (low thermal capacity)	1	3	2	84
102	Gas – fan assisted, electric ignition (high thermal capacity)	1	3	2	84
103	Gas – fan assisted, perm pilot light / unknown (low thermal cap)	1	3	2	80
104	Gas – fan assisted, perm pilot light / unknown (high thermal cap)	1	3	2	80
105	Gas – wall mounted (open/balanced flue)	1	2	2	66
106	Gas – floor mounted or back boiler (open/balanced flue)	3	2	2	66
107	Gas – unknown (open/balanced flue)	1	2	2	66
108	Gas – unknown flue type	1	2	2	75
109	Oil	4	2	2	71
110	Solid – manual feed (in heated space)	5	2	2	65
111	Solid – manual feed (in unheated space)	5	2	2	60
112	Solid – manual feed (unknown)	5	2	2	60
113	Solid – auto feed (in heated space)	5	2	2	70
114	Solid – auto feed (in unheated space)	5	2	2	65
115	Solid – auto feed (unknown)	5	2	2	65
116	Solid – back boiler (open fire)	5	2	2	63
117	Solid – back boiler (closed fire)	5	2	2	67
118	Solid – back boiler (unknown)	5	2	2	67
119	Solid – unknown	5	2	2	65
120	Electric – in heated space	6	2	2	100
121	Electric – in unheated space	6	2	2	85
122	Electric – unknown	6	2	2	85
123	Heat pump – ground source	14	2	2	320
124	Heat pump – water source	?	2	2	300
125	Heat pump – air source	15	2	2	250
129	Unknown	1	2	2	75
201	Electric Storage – old (large volume)	7	2	2	100
202	Electric Storage – modern slimline / convector	7	2	2	100
203	Electric Storage – modern slimline with fan	7	3	2	100
204	Electric Storage – unknown	7	2	2	100
301	Warm Air – gas/oil, with fan (ducted)	9	3	1	70
302	Warm Air – gas/oil, with fan (⍰oom heater)	9	3	1	69
303	Warm Air – gas/oil, with fan (unknown)	9	3	1	70
304	Warm Air – gas/oil, balanced/open flue (ducted, on-off control)	9	2	1	70
305	Warm Air – gas/oil, balanced/open flue (ducted, modular control)	9	2	1	72
306	Warm Air – gas/oil, balanced/open flue (ducted, heat recovery)	9	2	1	85
307	Warm Air – gas/oil, balanced/open flue (ducted, unknown)	9	2	1	76
308	Warm Air – gas/oil, balanced/open flue (Stub duct, no flue recov)	9	2	1	74
309	Warm Air – gas/oil, balanced/open flue (Stub duct, flue recovery)	9	2	1	85
310	Warm Air – gas/oil, balanced/open flue (Stub ducted, unknown)	9	2	1	80
311	Warm Air – gas/oil, balanced/open flue (condensing)	9	2	1	81

312	Warm Air – gas/oil, balanced/open flue (unknown)	9	2	1	78
313	Warm Air – electricaire	10	2	1	100
314	Warm Air – ground source heat pump	14	3	1	320
315	Warm Air – water source heat pump	?	3	1	300
316	Warm Air – air source heat pump	15	3	1	250
319	Warm Air – unknown	9	3	1	76
401	Communal/CHP – communal (dedicated boiler)	11	2	2	75
402	Communal/CHP – communal (waste heat from power station)	11	2	2	75
403	Communal/CHP – communal (unknown)	11	2	2	75
404	Communal/CHP – CHP	12	2	2	75
405	Communal/CHP – unknown	11	2	2	75
406	Communal/CHP – micro/domestic CHP (warm air)	12	2	1	75
407	Communal/CHP – micro/domestic CHP (radiator)	12	2	2	75
501	Electric – ceiling Heating	8	3	4	100
502	Electric – underfloor heating	8	3	4	100
503	Electric – unknown	8	3	4	100
601	Room Heater – gas (open flue)	1	1	1	63
602	Room Heater – gas (balanced flue)	1	2	1	58
603	Room Heater – gas (fan assisted flue)	1	3	1	72
604	Room Heater – gas (condensing)	1	2	1	85
605	Room Heater – gas (live effect, sealed to chimney)	1	2	1	40
606	Room Heater – gas (live effect, fan assisted flue)	1	3	1	45
607	Room Heater – gas (decorative fuel effect gas fire, open to chim)	1	1	1	20
608	Room Heater – gas (flueless gas fire)	1	2	1	90
609	Room Heater – gas (unknown)	1	2	1	59
610	Room Heater – Oil (fixed heaters)	4	1	1	55
611	Room Heater – electric (panel, convector or radiant heaters)	8	3	4	100
614	Room Heater – electric (unknown)	8	3	4	100
615	Room Heater – solid (open fire, in grate)	5	1	1	37
616	Room Heater – solid (open fire, in grate with throat restrictor)	5	1	1	37
617	Room Heater – solid (open fire, in grate with back boiler – no rads)	5	1	1	50
618	Room Heater – solid (closed room heater only)	5	2	1	65
619	Room Heater – solid (closed room heater, back boiler – no rads)	5	2	1	67
620	Room Heater – solid (unknown)	5	1	1	51
621	Room Heater – unknown	8	3	4	63
7777	Optical Reader Error	1	2	2	75
8888	Question not applicable – no primary heating	1	2	2	75
9999	Unknown	1	2	2	75

Table 4: EHS heating system types based on the 2007 EHCS surveyor briefing manual Part 1 (p.91). Mapping to one of fifteen high level heating systems is shown in column "Heating System"; mappings to the type of flue and heat emitters is also shown, as is a value for the system efficiency.

Each of these high level EHS system types is itself mapped to one of 15 high level systems, as shown in the "Heating Systems" column in the above table. This high level categorisation is much easier to handle elsewhere in the model, rather than having to consider individually each of the system types listed in the table above. The 15 system types are:

Main heating system	
1	Gas standard
2	Gas - combi
3	Gas back boiler
4	Oil standard
5	Solid boiler (house coal/anthracite)
6	Electric boiler
7	Electric storage
8	Electric room heater
9	Warm air - gas fired
10	Warm air - electric
11	Community heating without CHP
12	Community heating with CHP
13	Biomass boiler
14	Ground source heat pump
15	Air source heat pump

Table 5: Fifteen high-level heating system types, used in the modelling process.

Associated information on flues, heat emitters and the efficiency of the system has also been determined based on an assessment of SAP tables. This information is shown in Table 4 in the columns “Boiler flue”, “Heat emitter” and “System efficiency”, respectively. The heat system and heat emitter categories are considered in more detail in the appropriate sections below. System efficiency is a percentage based on assessing SAP 2009 Table 4a and 4b.

The flue type categories are:

Main heating - flue type	
1	Open
2	Balanced
3	Fan

Table 6: Flue types.

In many cases the flue type is explicitly stated in the heating system description in Table 4. In addition the following assumptions are made:

- Assume balanced flue if open/balanced.
- 108 Gas - unknown flue type: assume balanced flue. (SAP 2005 RdSAP Table S18)
- 109 Oil: assume oil pump not in heated space and open/balanced flue. (SAP 2005 RdSAP Table S18)
- 110-119 Solid: assume balanced flue.
- 120-122 Electric: assume balanced flue.

- 129 Unknown: assume Gas Standard.
- 319 Warm Air - unknown: assume gas/oil with fan (ducted).
- 401-407 Communal/CHP: assume wet system with radiators except 406 with warm air.
- 501-503 Electric ceiling/underfloor heating: assume electric room heater.
- 604, 607 and 608 Room heater - gas: assume balanced flue.
- 609 Room heater - LPG: assume the same as gas room heater with balanced flue.
- 621 Room heater - unknown: assume electric panel heater.
- 7777, 8888 and 9999: assume Gas (unknown), code 108.

On this basis each dwelling is allocated either one or zero open flues. This gives:

– **H024: Open flues - Main heating** (D048_OpenFlues_MainHeating)

Data on the secondary heating system is also assessed:

- Raw Physical\Services\finoheat: V091 - Other heating present
- Raw Physical\Services\finohtyp: V092 - Other heating system type

Only one of the secondary heating system types listed in V092 is associated with an open flue. Therefore if this system is present it is assumed there is an open flue, otherwise it is assumed that there isn't. Furthermore we add the condition stated above for chimney calculations, where a gas fire secondary heating system has been fitted since 1975 and the dwelling has a chimney stack. Combining this information gives:

– **H025: Open flues - Secondary heating** (D049_OpenFlue_SecondaryHeating)

Our default assumption is that there are zero open flues for the remaining open flue dataset required as input to the CHM:

– **H026: Open flues - Other** (H026_OpenFlues_Other)

To determine the number of extractor fans (intermittent fans) we use SAP 2005 RdSAP Table S5, which cross-references the number of habitable rooms (V041) against the SAP dwelling age band (H003) – both of which have been considered previously. Table S5 uses the SAP age band as a reference; this is one of the instances where we use the "AgeMapTable", relating the EHS age band to 2 SAP age bands if appropriate. This determines:

– **H027: Intermittent fans** (D050_ExtractorFansNumber)

For passive vents our default assumption is that there are zero, giving:

– **H028: Passive vents** (H028_PassiveVents)

If either the primary heating system (V085) or the secondary heating system (V091) are flueless gas fires then it is assumed that there is a flueless gas fire, otherwise it's assumed there is not one. This gives:

– **H029: Flueless gas fire** (D051_FluelessGasFire)

The determination of "D029_WallConstruction" was outlined above. This wall type is cross-referenced against a structural infiltration table, SAP Worksheet v9.90 Box 11, giving:

- **H030: Structural Infiltration** (D052_StructuralInfiltration)

The floor construction type is determined using data on the living room and kitchen floors:

- Raw Physical\Interior\finlivle: V078 - Living room floor level
- Raw Physical\Interior\finkitle: V079 - Kitchen floor level
- Raw Physical\Introoms\finflrsf: V080 - Living room - solid floor
- Raw Physical\Introoms\finflrsf: V081 - kitchen - solid floor

The living room and kitchen are assessed (V078 & V079) to determine whether they're at either the basement or ground floor level. If neither are at these levels it is assumed that the nature of the floor is unknown – for which the default assumption is that there is a solid floor; if either room is at one of these levels the nature of their floors is assessed (V080 & V081) to determine whether either is solid; if so the floor is assumed to be solid otherwise it is assumed to be suspended timber. Combining this information with the SAP dwelling age (H003) (this is one of the instances where we use the "AgeMapTable", relating the EHS age band to 2 SAP age bands if appropriate) and cross-referencing against SAP Worksheet v9.90 Box 12 and SAP Table S5, the floor infiltration is determined:

- **H031: Floor Infiltration** (D053_FloorInfiltration)

We determine whether or not there is a draught lobby by cross-referencing the dwelling type (H005) against SAP 2005 RdSAP Table S5, thus giving:

- **H032: Draught Lobby** (D054_DraughtLobby)

Assessing the two datasets about the extent of double glazing in each dwelling (V075 & V076), considered previously for determining window areas, the extent of double glazing is also taken as the extent of "Windows and doors draught-stripped" – thus giving us:

- **H033: Windows and doors draught stripped** (D055_WindowsDoorsDraughtstripped)

We use a default assumption for the type of ventilation system for all properties – that is that they are all naturally ventilated. This gives us:

- **H035: Ventilation System** (H035_VentilationSystem)

4. Other Heat Loss Elements

For doors a default U-value of 3.0 $W/m^2.K$ is assumed, based on SAP 2005 RdSAP Table S15A. This gives:

- **H037: Door U-value** (D058_DoorUValue)

The extent of single glazing (Windows 1 Type), and double glazing (Windows 2 Type) has been considered above, and the respective areas determined (H039 and H044). Based on this information the exact type of window is determined. If either window types 1 or 2 have zero area then their types are defined as "not applicable"; otherwise windows type 1 is defaulted as "Single Glazing" and windows type 2 is defaulted as "Double glazing (air filled)". This gives us:

- **H038: Windows 1 Type** (D068_Windows1Type)
- **H043: Windows 2 Type** (D070_Windows2Type)

The window frame type is determined using the EHS dataset:

- Derived\physical\typewin: V077 - Windows predominant type

For both single and double glazing (windows type 1 and 2) and again assessing whether there is zero area for either type (H039 and H044), the window frame type is determined as either "not applicable" or as the predominant type defined in V077. This gives us:

- **H040: Windows 1 Frame** (D071_Windows1FrameType)
- **H045: Windows 2 Frame** (D072_Windows2FrameType)

Windows over-shading and orientation is all based on default assumptions. For both windows type 1 (single glazing) and type 2 (double glazing) the over-shading is assumed to be "average or unknown (20-60% obstruction)" whilst the orientation is assumed to be "East / West". This gives us:

- **H041: Windows 1 Overshading** (H041_Windows1Overshading)
- **H042: Windows 1 Orientation** (H042_Windows1Orientation)
- **H046: Windows 2 Overshading** (H046_Windows1Overshading)
- **H047: Windows 2 Orientation** (H047_Windows1Orientation)

We use a default assumption that there is no roof window. Therefore the roof window type, frame and orientation are all assumed "not applicable", whilst the roof window area is assumed to be zero. This gives us:

- **H048: Roof Window Type** (H048_RoofWindowType)
- **H049: Roof Window Area** (H049_RoofWindowArea)
- **H050: Roof Window Frame** (H050_RoofWindowFrame)
- **H051: Roof Window Orientation** (H051_RoofWindowOrientation)

Using the data on the extent of any heat loss area for both the basement and the ground floor (H053 and H056 considered previously), if either is zero then the corresponding floor construction type is "not applicable"; otherwise the floor type is assumed to be as for the determination of floor infiltration above (H031). This gives us:

- **H052: Basement Floor Construction** (D074_BasementFloorConstructionType)
- **H055: GF Construction** (D075_GroundFloorConstructionType)

We assume that there is no Exposed Floor, therefore the Exposed Floor Construction is deemed "not applicable" and the Exposed Floor Heat Loss Area is assumed to be zero. This gives us:

- **H058: Exposed Floor Construction** (H058_ExposedFloorConstruction)
- **H059: Exposed Floor Heat Loss Area** (H059_ExposedFloorHeatLossArea)

- Derived\physicsl\typercov: V082 - Predominant type of roof covering
- Derived\physicsl\typerstr: V083 - Predominant type of roof structure
- Raw Physical\Services\flithick: V084 - Loft insulation thickness

V082 – V084 provides us with data on the roof type. We combine the information in V082 & V083 to determine a roof construction (cross-referencing these two pieces of information). This gives us:

- **H067: Roof Construction** (D079_RoofConstruction)

V084 provides loft insulation thickness, giving us:

- **H068: Loft Insulation** (D080_LoftInsulationThickness)

Where there is no room-in-roof (H071=zero) we assume that the room-in-roof construction is "not applicable", otherwise we use the roof construction (H067) to determine the room-in-roof construction:

- **H070: Roof - room in roof Construction** (D081_RoomInRoofConstruction)

We assume that any party wall construction type is "Single plasterboard on dabs on both sides, dense blocks, cavity" giving:

- **H072: Party Wall Construction** (H072_PartyWallConstruction)

We assume that any party floor construction type is "Precast concrete planks floor, screed, carpeted" giving:

- **H074: Party Floor Construction** (H074_PartyFloorConstruction)

We assume that any party ceiling construction type is "Plasterboard ceiling, carpeted chipboard floor" giving:

- **H076: Party Ceiling Construction** (H076_PartyCeilingConstruction)

Based on dimensional information already generated, we use simplistic assumptions as follows, to calculate internal walls, floors and ceilings areas:

Internal walls area is equal to the total façade area, that is external wall area + window area + door area, where external walls = exposed + attached (party walls) + semi-exposed walls (for flats only).

- **H079: Internal Wall Area** (H079_InternalWallArea)

For internal floors & ceilings we treat houses and flats separately, and also differentiate between single storey flats and flats with more than one storey.

For houses assume total floor area = heat loss floor area + Internal floor area, so Internal floor area = total floor area – heat loss floor area (that is basements + ground floor). Also for houses assume internal ceiling area = internal floor area + roof area. This is based on the assumption that we want an "extra" internal ceiling area equal to the roof area, in addition to an internal ceiling area equal to the internal floor area. This “extra” ceiling area is separate to the roof heat loss area and any room-in-roof heat loss area.

For 1 storey flats the floor area will already be accounted for in either heat loss floor area or party floor area, so internal floor area always = 0. For ceilings, for all flats other than top floor flats, the ceiling area will already be accounted for in party ceiling area, so internal ceiling area always =0**. For** top floor flats we assume there is an internal ceiling area which is equal to the roof area (as described for houses above).

For flats with more than 1 storey, for NON top floor flats the internal floor areas & internal ceiling areas both equal the total floor area minus the lowest storey floor area. For top floor flats internal floor area is the same as NON top floor, but internal ceiling area again has an additional area equal to the roof area.

Together this gives us:

- **H081: Internal Floor Area** (H081_InternalFloorArea)
- **H083: Internal Ceiling Area** (H083_InternalCeilingArea)

For internal features types, without further information we make the following simplistic assumptions: (i) Internal wall = type 2, "dense block, dense plaster", (ii) internal floor = type 6, "Timber I-joists, carpeted", and (iii) internal ceiling = type 1, "Plasterboard ceiling, carpeted chipboard floor". This gives:

- **H078: Internal Wall Construction** (H078_InternalWallConstruction)
- **H080: Internal Floor Construction** (H080_InternalFloorConstruction)
- **H082: Internal Ceiling Construction** (H082_InternalCeilingConstruction)

5. Space Heating

- Raw Physical\Services\ Finchbma: V131 - Primary heating boiler brand[3]
- Raw Physical\Services\ Finchbmo: V132 - Primary heating boiler model[3]

When the primary heating system is a boiler, we try to locate the exact boiler type in the SAP Product Characteristics Database (PCD) - previously known as SEDBUK. V131 and V132 give the boiler brand and model recorded by the assessor. First, a number of common mis-spellings in the brand names are checked for and corrected (e.g. Vaillant is often misspelled as Valliant in the EHS data). The PCD is then searched to find the closest match for the specified brand and model.

Two types of text comparison are used in the search – exact matches, where the text in the EHS variables exactly matches text in the PCD, and inexact matches, where the text from the PCD contains the text in the EHS variables along with other data. For example if the EHS lists the model as "Ti30", then an inexact match would class this as being a match for "Ti30-AX" in the PCD, but not a match to "Ti-AX-30". The PCD is searched as follows:

- If a boiler with an exact brand and model match exists, then choose that one (or choose the first one if more than one exact match is found).
- If a boiler with an exact brand match and an inexact model match is found, then select that boiler.
- If a boiler with an exact model match and inexact brand match is found, then select that one. This covers cases where for example Potterton boilers sometimes have "Potterton" as the brand in the PCD and sometimes have "Potterton International Heating".
- Finally check for an inexact brand match and inexact model match.
- If previous steps fail to identify the boiler, a fallback approach is used based on cross-referencing the primary heating appliance code (V085) (see below).

Where the exact boiler type cannot be identified, or where the primary heating system is not a boiler, each of the Primary heating appliance codes (V085) are mapped to one of 15 high level main heating system types, as shown previously in table 3. The 15 high-level system types, shown previously in Table 4, are repeated here:

1. Gas standard
2. Gas – combi
3. Gas back boiler
4. Oil standard
5. Solid boiler (house coal/anthracite)
6. Electric boiler
7. Electric storage
8. Electric room heater
9. Warm air - gas fired

[3] Already mentioned in Section 3 but repeated here to clarify the approach to identifying the heating system.

10. Warm air – electric
11. Community heating without CHP
12. Community heating with CHP
13. Biomass boiler
14. Ground source heat pump
15. Air source heat pump

- Raw Physical\Services\finmhboi: V086 - Primary heating boiler type

Although we have a mapping from the V085 EHS data to the high-level list of heating systems in Table 3, the EHS contains additional heating system information in terms of the Primary Heating Boiler Type V086. In particular V086 identifies back boiler and combi boilers. It is feasible that a number of the heating systems classed as "Gas Standard" (category 1) in Table 3 are actually back boilers or combi, which are categories 3 and 2 respectively in the list above. Therefore we combine the information in Table 3 with V086 to reclassify gas standard systems as gas back boilers or gas – combi, where appropriate. In all other circumstances the system identified in the mapping Table 3 is assumed. This gives:

   - **H101: Main Heating System** (D082_MainHeatingSystemType)

- RawPhysical\Services\finmhfue: V087 - Primary heating fuel type

If the main heating system (H101) is electric or is a ground source or air source heat pump, then V087 the primary heating fuel type is used to determine the main heating electric tariff, otherwise this is not applicable:

   - **H102: Main Heating - Electric Tariff** (D083_MainHeatingElectricTariff)

If the main heating system is Community Heating it is assumed that: the Main heating community heating tariff is "Usage based charging", the Main heating community heating fuel type is Gas; specifically if the main heating system is Community heating with CHP it is assumed that the "Main heating community heating - CHP fraction" is 0.35 and that the "Main heating community heating - CHP fuel" is Gas. This gives us:

   - **H103: Main Heating - Community Heating Tariff** (D084_MainHeatingCommunityHeatingTariff)
   - **H104: Main Heating - Community Heating Fuel Type** (D085_MainHeatingCommunityHeatingFuel)
   - **H105: Main Heating - Community Heating CHP Fraction** (D086_MainHeatingCommunityHeatingCHPFraction)
   - **H106: Main Heating - Community Heating CHP Fuel** (D087_MainHeatingCommunityHeatingCHPFuel)

Using SAP 2009 Tables 4a, 4b and RdSAP Table S18 we can associate each of the Primary heating appliance codes (V085) with information on the "Main heating heater flue", the "Main heating heat emitter" and the "Main heating efficiency (%)", giving:

– **H107: Main Heating - Heater Flue** (D088_MainHeatingHeaterFlue)[4]
– **H109: Main Heating - Heat Emitter** (D090_MainHeatingHeatEmitter)
– **H110: Main Heating Efficiency** (D091_MainHeatingEfficiency)

If the main heating system type (H101) is anything other than “standard oil” then it is assumed that the “Main heating oil pump location” is “not applicable”; for a standard oil system it is taken that the oil pump is located “Outside dwelling”. This gives us:

– **H108: Main Heating - Oil Pump Location** (D089_MainHeatingOilPumpLocation)

- Raw Physical\Services\finchtim: V088 - Primary heating control - central timer
- Raw Physical\Services\finchrom: V089 - Primary heating control - room thermostat
- Raw Physical\Services\finchtrv: V090 - Primary heating control – TRVs

V088 – V090 are used to determine which primary heating controls are present:

– **H111: Main Heating Control - Programmer** (D092_MainHeatingControl_Programmer)
– **H112: Main Heating Control - Room Thermostat** (D093_MainHeatingControl_RoomThermostat)
– **H113: Main Heating Control – TRVs** (D094_MainHeatingControl_TRVs)

- Raw Physical\Services\finoheat: V091 - Other heating present
- Raw Phyaicsl\Services\finohtyp: V092 - Other heating system type

V091 and V092 are used to determine the presence and nature of the Secondary heating system, giving:

– **H114: Secondary Heating System** (D095_SecondaryHeatingSystem)

[4] Note that although we consider the flue associated with the main heating system twice, once in H024 and once in H107, this doesn't affect the subsequent model calculations. H024 considers open flues only, and this information is subsequently only used as an input to ventilation calculations, whereas H107 considers all flue types and is subsequently only used as an input to the space heating calculations.

6. Hot Water System

- Raw Physical\Services\finwhcpr: V093 - Hot water system with central heating

  V093 is used to identify whether the hot water system is with the central heating:

  - **H085: DHW Boiler with Central Heating** (D096_DHWSystemWithCentralHeating)

- Raw Physical\Services\finwhopr: V094 - Boiler (water heating only) – present
- Raw Physical\Services\Finwhoty: V095 - Boiler (water heating only) – type
- Raw Physical\Services\finwhxpr: V096 - Back boiler (water heating only) – present
- Raw Physical\Services\finwhxty: V097 - Back boiler (water heating only) – type
- Raw Physicsl\Services\finwsipr: V098 - Single immersion heater – present
- Raw Physicsl\Services\finwsity: V099 - Single immersion heater – type
- Raw Physical\Services\finwdipr: V100 - Dual immersion heater – present
- Raw Physicsl\Services\finwdity: V101 - Dual immersion heater – type
- Raw Physical\Services\finwsppr: V102 - Separate instantaneous heater (single point) – present
- Raw Physical\Services\finwspty: V103 - Separate instantaneous heater (single point) – type
- Raw Physical\Services\finwmppr: V104 - Separate instantaneous heater (multi point) – present
- Raw Physical\Services\finwmpty: V105 - Separate instantaneous heater (multi point) – type
- Raw Physical\Services\finwhlpr: V106 - Communal – present
- Raw Physical\Services\finwhlty: V107 - Communal - type

The nature of the Domestic Hot Water system is determined by the information in EHS datasets V093 – V107. If none of these datasets specify the DHW system then it is assumed that if the main heating system (H101) is gas then the DHW system is “standard gas”, otherwise it is assumed to be an electric boiler. This determines:

- **H084: DHW System** (D097_DHWSystemType)

If H084 is “other electric” then the DHW electric system type is also assumed to be “other electric”; otherwise if H084 is anything other than “Electric Boiler” then the DHW electric system type is assumed to be “not applicable”; otherwise if V098 shows that there is a single immersion present then the DHW electric system type is assumed to be “single immersion”; otherwise if V100 shows that there is a dual immersion present then the DHW electric system type is assumed to be “dual immersion”; otherwise the default is “single immersion”. This gives us:

- **H086: DHW Electric System Type** (D098_DHWElectricSystemType)

If H086 is “not applicable” it is assumed that the DHW electric system tariff is also “not applicable”; otherwise if the hot water system is with the central heating and H102 the main heating electric tariff is stated then the DHW electric system tariff is assumed to be the same as H102; otherwise if H086 is “other electric” then the DHW electric system tariff is assumed to be the “standard tariff”; otherwise if H086 is either a single or dual immersion then it is cross-referenced against conversion tables to determine the tariff. This gives us:

- **H087: DHW Electric System Tariff** (D099_DHWElectricSystemTariff)

If H084 is a community heating system then the DHW Community Heating Tariff is assumed to be "Usage based charging", otherwise it is assumed to be "not applicable", giving:

- **H088: DHW - Community Heating Tariff** (D100_DHWCommunityHeatingTariff)

If H084 is a community heating system then the DHW community heating fuel type is assumed to be Gas, otherwise it is assumed to be "not applicable", giving:

- **H089: DHW - Community Heating Fuel Type** (D101_DHWCommunityHeatingFuel)

If H084 is a community heating system with CHP then the DHW community heating - CHP fraction is assumed to be 0.35, otherwise it is assumed to be zero, giving:

- **H090: DHW - Community Heating CHP Fraction** (D102_DHWCommunityHeatingCHPFraction)

If H084 is a community heating system with CHP then the DHW community heating - CHP fuel is assumed to be Gas, otherwise it is assumed to be "not applicable", giving:

- **H091: DHW - Community Heating CHP Fuel** (D103_DHWCommunityHeatingCHPFuel)

If H085 identifies that the hot water system is with the central heating, the DHW system efficiency is assumed to be the same as H110 the Main Heating Efficiency, otherwise H084 is cross-referenced against efficiency figures in SAP 2009 Table 4a to identify the efficiency. This gives:

- **H092: DHW System Efficiency** (D104_DHWSystemEfficiency)

- Raw Physical\Services\finwhsiz: V108 - Hot water cylinder volume
- Raw Physical\Services\finwhins: V109 - Hot water cylinder insulation type
- Raw Physical\Services\finwhmms: V110 - Hot water cylinder insulation thickness
- Raw Physical\Services\finwhthe: V111 - Hot water cylinder thermostat
- Raw Physical\Services\finwotfu: V112 - Hot water system - other fuel code

If H084 is an electric boiler and V108 the hot water cylinder volume is zero, then a default DHW cylinder volume of 110 litres is assumed; otherwise the cylinder volume specified in V108 is assumed. This gives:

- **H093: DHW Cylinder Volume** (D105_DHWCylinderVolume)

The hot water cylinder insulation type is taken from V109, giving:

- **H094: Cylinder Insulation Type** (D106_DHWCylinderInsulationType)

The hot water cylinder insulation thickness is taken from V110, giving:

- **H095: Cylinder insulation Thickness** (D107_DHWCylinderInsulationThickness)

It is assumed that the Primary Pipe-work is insulated for post 1995 dwellings; otherwise it is "un-insulated":

- **H096: Primary Pipe-work Insulation** (H096_DHWPrimaryPipeworkInsulation)

The presence of a hot water cylinder thermostat is taken from V111, giving:

- **H097: Cylinderstat** (D108_DHWCylinderstat)

The presence of a Solar DHW system is assessed from V112, giving:

- **H098: Solar DHW** (D109_SolarDHWSystem)

If, from H098, there is a solar DHW system, and if H093 the DHW cylinder volume is non-zero, then it is assumed that there is “Solar DHW in cylinder”; otherwise if there is a solar DHW system but the DHW cylinder volume is zero it is assumed that there isn’t “Solar DHW in cylinder”:

- **H099: Solar DHW in Cylinder** (D110_SolarDHWInCylinder)

If from H098 & H099, there is NO solar DHW, then the Solar DHW storage is assumed to be zero; otherwise if from H098 & H099 there is solar DHW but there is no solar DHW in cylinder, then it is assumed that the Solar DHW storage is 75 litres (if separate solar cylinder - from SAP 2005 Appendix T: Table T2, Item N); otherwise if from H098 & H099 there is solar DHW and there is solar DHW in cylinder, then it is assumed that the Solar DHW storage is half the size of H093 the DHW cylinder volume. This gives us:

- **H0100: Solar DHW Storage** (D111_SolarDHWStorage)

7. Low Energy Lighting

- Raw Physical\Introoms\finhtglg: V113 - Low energy light - living room, V114 - Low energy light – kitchen, V115 - Low energy light – bedroom, V116 - Low energy light – bathroom, and V117 - Low energy light – circulation

The presence of low energy lighting throughout the dwelling is determined from V113 – V117. Using BREDEM-8 Section 4.2 Low energy lights, a weighting factor is obtained associated with the proportion of LEL in the entire property relative to each of the rooms represented by V113 – V117. The presence of LEL for each room is multiplied by the associated weighting and these calculated values are summed over all rooms to determine the fraction of LEL in the entire dwelling:

- **H115: Low Energy Lighting** (D112_LowEnergyLightsFraction)

References

1. Firth, S.K., Lomas, K.J., Wright, A.J. 2010. Targeting household energy-efficiency measures using sensitivity analysis. Building Research and Information 38 (1), 25-41.
2. Cheng, Vicky & Steemers, Koen. 2011. Modelling domestic energy consumption at district scale: A tool to support national and local energy policies. Environmental Modelling & Software 26(10) pp. 1186-1198.